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Entomology in the Army[1]

W. D. Reed,[2] R. W. Bunn,[2] and F. S. Blanton[3]

The entomological problems of the Army were given slight consideration during World War I. In overseas areas where the Army was in action malaria was not a serious threat, and comparatively little thought was given to mosquito control. Troops engaged in trench warfare often became infested with lice despite control measures then available, but typhus fever did not develop in our troops. In this country some mosquito control was practiced in and around southern camps, and about 3 million dollars was spent for this purpose in 1918 and 1919. Control efforts were not completely successful since 9617 cases of malaria were reported among troops in the United States, with a total of 115,181 days lost from training. Control of obnoxious and destructive insects received but scant attention.

Recognizing the need for entomological service, the War Department provided for commissioning entomologists as Sanitary Corps officers, Organized Reserve Corps, following World War I. These reserve officers were ordered to active duty in 1941 and were assigned to military installations in the South where malaria was a potential hazard to troops undergoing training. They served as the nucleus from which developed the entomological services of World War II.

After the United States entered the war, additional entomologists were recruited for the Sanitary Corps, and a total of about 250 were eventually obtained from various civilian sources. More than 80 per cent of these were assigned to overseas theatres and served with distinction in the Pacific, Europe, China, Burma, India, the Mediterranean region, and in fact, wherever insect problems confronted the Army.

At the outbreak of World War II, entomological service was provided by entomologists and sanitary engineers of the Medical Department, and major emphasis was placed on the control of disease-bearing insects. In this country a malaria control program was established which succeeded in holding the malaria rate to 1.8 per thousand per year in 1941 and further reduced the rate each succeeding year to a low of 0.1 in 1945.

Fig. 1.—Malaria control detachment applying DDT dust with rotary hand dusters for control of mosquitoes in marshy area. Italy, 1945

In 1942 the War Department General Staff defined responsibility for the various phases of insect and rodent control essentially as follows: Corps of Engineers, supervision and execution of control measures; Medical Department, recommendations, advice, and necessary technical supervision; Quartermaster Corps, procurement, storage and supply of general issue insecticides, rodenticides, and equipment. The supply function of the Quartermaster Corps was discharged by the regular supply organization; Sanitary Corps entomologists and sanitary engineers carried on the duties of the Medical Department and an Insect and Rodent Control Section was established in the

[1] Richmond Program Paper.
[2] Insect and Rodent Control Section, Office of the Chief of Engineers.
[3] Major, Pharmacy Corps, Office of the Surgeon General.

Office of the Chief of Engineers to meet the responsibility of that Corps in the United States. Entomologists, predominantly civilians, were employed at Headquarters of Service Commands to supervise the work of the Corps of Engineers and to train supervisors, foremen, and operators at posts, camps and stations. Under this system in the Zone of the Interior control measures were undertaken for pests that affect the health, morale and efficiency of personnel and that damage or destroy supplies and equipment. The work included the control of such pests as mosquitoes, flies, cockroaches, bedbugs, ticks, mites, fleas, ants, termites, Lyctus beetles and other wood-destroying insects, pests of trees and shrubs, insects attacking flour and other items of subsistence, rats, mice, and field rodents. Sanitary Corps entomologists were assigned to the various Service Command Headquarters, the larger posts, and to medical laboratories, and conducted investigations, furnished technical assistance, and provided laboratory service. The cooperative efforts of the Medical-Engineer team produced effective and efficient control and reduced losses from insects and rodents to a minimum.

FIG. 2.—Spraying river with DDT solution from amphibian jeep for control of mosquitoes in India.

In overseas theatres responsibility for insect and rodent control operations remained with the Medical Department for the duration of the war. Entomologists of the Sanitary Corps were assigned to headquarters of major commands, general laboratories and to other positions where they could provide useful service. Malaria Control Detachments and Malaria Survey Detachments were organized to provide in small units the personnel and equipment needed to investigate malaria vectors and to plan and supervise control programs. Control detachments consisted of an officer, usually a sanitary engineer, and 11 enlisted men, mostly trained technicians. Survey detachments were composed of two officers, an entomologist and a parasitologist, and 11 enlisted men, mostly technicians. These units served in all parts of the world with marked success, both in actual control work accomplished and in contributing to malaria discipline and education (Figs. 1 and 2). Malaria rates in overseas theatres reached a peak in June, 1943, but dropped thereafter in the face of continued operations in highly malarious areas with constantly increasing numbers of troops. In most theatres the decline in malaria rates coincided closely with the building up of the malaria control organization.

With the end of the war, the rapid demobilization of the Army, and its reorganization, certain changes have been made in the entomological services of the Army. The Medical Department has provided for the commissioning of entomologists in the Regular Army. At the present time applications for these positions are being received by the Adjutant General, and any entomologist who has served in the Army and is interested in a career as an Army entomologist should apply before December 31, 1946. Those accepted will be integrated as Pharmacy

FIG. 3.—Disc harrowing to eliminate mosquito breeding in checked soil. Wood cleats attached to tractor tread to permit operations on unstable soil.

Corps officers as an interim measure, and will be assigned to major headquarters, laboratories and overseas commands to provide the service for which the Medical Department is responsible. Civilian entomologists are employed under Civil Service regulations by the Chief of Engineers, the Engineers for Repairs and Utilities at the headquarters of the six Army Areas, and at the major Army Air Forces commands. In addition, expansion to include permanent overseas bases is now in progress, and control operations in these areas are being taken over by the Corps of Engineers as demobilization of the Medical Department's control units proceeds. A limited number of malaria control and malaria survey detachments will be maintained in an active status by the Medical Department in the post war period, to provide a trained nucleus for expansion should the need again arise. These detachments will probably be reorganized on the basis of war experience to provide more effective service for Army units in the field.

The following resume of entomological activity in the Army in the United States in 1946 indicates the variety of problems encountered.

MOSQUITOES.—Control of mosquitoes continues to be a major Army problem. The anopheline mosquitoes are of course given primary consideration, but it has also been necessary to control pest mosquitoes in those instances where they have become so abundant as to affect the morale and efficiency of personnel. Control operations against larvae include the customary measures such as draining, filling, and larviciding. Disc harrowing has also been used where mosquito breeding has been found in checked soil (Fig. 3). DDT in diesel oil is the larvicide generally used, and application is customarily made with the cylindrical 3-gallon compressed air sprayer developed by the Corps of Engineers. Treatment of screens with DDT and residual spraying of building interiors is practiced to control adult mosquitoes. Airplane spraying for mosquito control in the United States has been conducted in 1946 by Squadron D, 313th AAF Base Unit, Tactical Air Command. Personnel of the squadron included pilots, entomologists, mechanics and other operating personnel. Equipment consisted of three *C-47* aircraft each equipped with a 675-gallon tank and gravity flow system leading to a vertical streamlined discharge pipe. An electrically controlled discharge valve operated from the pilot's compartment was provided for releasing the spray. Spray solution used was 20 per cent DDT in fuel oil plus 28 per cent auxiliary solvent (*Vesicol NR 70* or *Culicide B*). Spray missions were accomplished at 10 Army installations, and a total of 89,224 acres was covered with an average dosage of 0.235 pound of DDT per acre. Costs averaged 44 cents per acre. Observations indicate an immediate average reduction of adult mosquitoes of approximately 90 per cent was obtained. Duration of effectiveness was from 2 to 3 weeks.

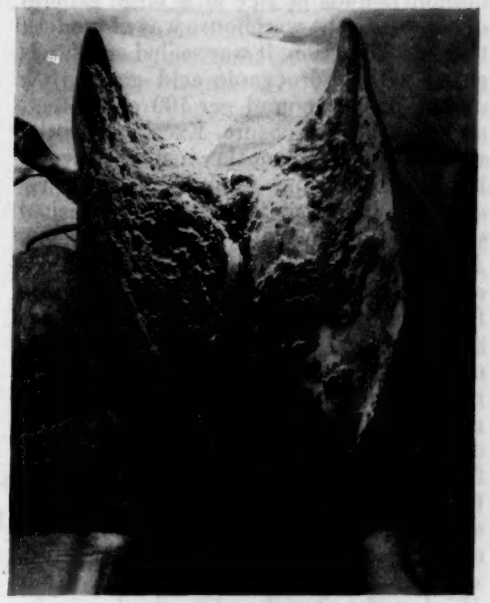

FIG. 4.—Sheepskin lining of full-rigged packer's saddle severely damaged by clothes moths.

FLIES.—Control efforts for house flies were directed at elimination of breeding areas and treatment of screens, outdoor resting places, kitchens and mess halls with a residual application of DDT.

COCKROACHES.—Infestations of cockroaches in mess halls are a common problem at military installations. DDT is the insecticide used for control, usually as a residual spray, but sometimes the spray is augmented by DDT dust. Reports have been received that poor results were obtained with DDT for cockroach control.

However, in all cases investigated, it has been found that faulty application technique has been largely responsible for poor results, and when corrected, satisfactory control has resulted.

BEDBUGS.—Since the advent of DDT, bedbugs have ceased to be a problem on Army posts. Thorough treatment of barracks with DDT gives complete kills, and barracks remain free of infestation for a period of a year or more.

SUBSISTENCE INSECTS.—Flour, rice coffe, macaroni, and other items of subsistence in storage in Army depots are sometimes found infested with various flour moths and beetles. A problem of this type encountered during the past summer was an infestation discovered in about 20 million pounds of rice at a large general depot. Since the warehouse was of modern tight construction, it was sealed and fumigated with hydrocyanic acid gas with a dosage of 0.72 pound per 100 cubic feet, and a 48 hour exposure. Excellent results were obtained. In another instance several hundred thousand pounds of flour required fumigation. This was accomplished with methyl bromide in tight boxcars. After fumigation the flour was re-bolted and re-sacked. Permanent fumigation facilities are not available at the large Army general depots and Quartermaster depots at present. However, steps are now being taken to install vacuum fumigation chambers at the principal Army depots in order that a safe, rapid and effective control method will be available to combat insect infestations in subsistence items. Atmospheric fumigation chambers installed at many depots provide a means of treatment for small lots of infested materials.

CLOTHES MOTHS.—Large quantities of woolen goods are in storage in various Army depots. Infestations of clothes moths have been detected in a few instances, and protection of this material from damage while in storage is a major problem. An idea of the magnitude of the problem can be obtained from data for one depot where rolls of woolen uniform cloth approximately 5 feet in length and 12 to 16 inches in diameter are stored. There are at present 10 to 12 warehouse bays filled with this material, each bay containing about 30,000 rolls. Protection in the past has been achieved through the liberal use of naphthalene applied when stacking. However, the naphthalene is lost through sublimation, and must be replaced every 6 to 12 months. This was formerly done by tearing down the stacks and adding naphthalene while restacking. This process naturally resulted in a high labor cost. The entomologist in this Army area, working with storage officers of the depot, has developed a method of blowing the naphthalene into the interstices between the folls with an air stream from a vacuum cleaner, with a resultant saving in the labor cost of about 90 per cent.

Clothes moths have also been found damaging the sheepskin linings of packers' saddles (Fig. 4), saddle blankets, and mohair saddle girths, necessitating fumigation to destroy the infestation.

FIG. 5.—Dipping hardwood storage pallets into pentachlorophenol solution for control of Lyctus beetles.

LYCTUS BEETLES.—Lyctus beetles have been a problem in hardwood tool handles and in pallets used for stacking supplies in storage depots. At one depot the problem was solved by setting up a large tank or dipping vat containing 5 per cent pentachlorophenol. A framework or cage was devised for holding a number of the pallets and a crane was used to raise the cage, dip the pallets into the solution and then place them on a drainage rack. As pallets are freed during the course of operations, they are treated and marked before returning them for further use (Fig. 5.)

TERMITES.—Subterranean termites cause considerable damage to Army buildings in the eastern and southern parts of the United States. At a number of posts, it has been necessary to establish control programs involving the use of soil poisons

such as pentachlorophenol, orthodichlorobenzene and DDT, and the correction of structural practices that favor termite infestation.

The need for entomological research is recognized by the Army. Many of the developments in insect control of the past few years were facilitated through the backing of the War Department. At the present time research is continuing on a number of projects in which the Army has primary interest. This work is sponsored by various agencies of the War Department including the Medical Department, the Corps of Engineers, the Quartermaster Corps and the Chemical Corps. Research is accomplished either by the research and development divisions of the various services, or by agreements with other governmental agencies or universities, frequently aided by a transfer of funds.

Teaching Army personnel of all ranks something of the importance of insects, particularly in relation to disease transmission is a matter claiming the attention of entomologists of the Army Medical Department. The individual soldier must be aware of the danger resulting from the bite of a mosquito, a mite, or a flea, and know what he can do to avoid it. Line officers from second lieutenant to general must also be aware of the fact that frequently more soldiers are removed from combat by insects than by enemy bullets. To prevent such losses, insect control must be given suitable emphasis and priority, provision must be made for skilled entomological personnel empowered to operate wherever and whenever the need arises, and supplies and equipment must be available when and where needed. To the commander operating in a highly malarious area, DDT may be as important as gasoline or ammunition. Entomologists providing this instruction for Army personnel are performing a valuable service, and the degree of success they achieve in impressing Army personnel with the military importance of insects will greatly influence the future of insect control operations in the Army.

Entomology has won deserved recognition in the Army. The substantial nature of that recognition is evidenced by the provisions for commissioning entomologists in the Regular Army and for hiring civilian entomologists under civil service regulations to provide insect and rodent control service. These entomologists are working together to reduce the incidence of insect-borne disease to a minimum, to control those insects adversely affecting efficiency and morale of Army personnel, and to prevent insect damage to Army supplies, equipment and property. Judging from the success they have achieved to date, entomology is in the Army to stay.—1-15-47.

Effects of Temperature and Humidity on Larval and Pupal Stages of the Common Cattle Grub

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Both the common cattle grub and the heel fly *Hypoderma lineatum* (De Villers) and *Hypoderma bovis* (Degeer), are major pests of cattle in Wyoming. Damage is caused by both larvae and adults. The larvae cause irritation and inflammation when they penetrate the skin, migrate through the animal, and form cysts in the back. They also cause much damage to leather because of their habit of cutting holes through the skin of the back. The flies interfere with normal grazing and limit weight gains and milk production by chasing and frightening cattle.

The heavy loss to the cattle industry has been realized for a long time but only recently has the control of cattle grubs been attempted to any great extent. Only a few thousand head of cattle were treated for grubs in 1941 and 1942 in Wyoming. However, in succeeding years, a good proportion of the million cattle in the state has been treated. In 1943, 69,000 animals were treated; in 1944, 140,891; in 1945, 225,295; and in 1946, approximately 252,100.

The life cycle of both species of cattle

[1] I wish to acknowledge my indebtedness to Dr. A. C. Hodson, Division of Entomology and Economic Zoology, University of Minnesota, and to Dr. L. F. Clarke, Zoology Department University of Wyoming, for critically reading the manuscript and making valuable suggestions; to Dr. B. T. Snipes, State Entomologist and to Mr. Roy S. Cooper, Deputy State Entomologist of Wyoming for pointing out the need for this study, and to Miss Eileen Clark for assistance in obtaining seasonal history data.

grub is quite similar except that *Hypoderma lineatum* appears about a month sooner in all stages than does *H. bovis* and consequently is exposed at certain periods to more severe cold temperatures. The life cycle of *H. lineatum*, together with the seasonal cycle at Laramie, is given here.

Flies emerge in May and live for only a short time. During this brief period the females lay eggs on the hairs of the legs and other lower parts of cattle. The eggs hatch in 3 to 6 days and the young larvae bore through the skin. The minute larvae migrate within the host and finally, 8 to 9 months later, usually some time in February, reach the back. When a young larva reaches the back of an animal it perforates the skin to the outside and forms a cyst in which it molts twice and becomes fully grown in about 40 days. The fully developed larvae crawl through the holes in the back and drop to the ground in March and April. The free larvae come to rest in the dead grass and other debris on the ground surface, or in small pits that they themselves form in the ground. After 1 to 4 days, the larvae enter the pupal stage which lasts about 40 to 50 days. Flies emerge from the puparia in May and continue the propagation of the species.

Low temperature has been suspected as being a lethal factor in the life of *Hypoderma lineatum*, since grubs dropping from the backs of animals in March at Laramie and in February at lower altitudes in the state and adjoining areas are often subjected to extremely cold and inclement weather. For this reason, many stockmen and pest control operators have felt that the early dropping grubs might be disregarded in control of the species. This paper has attempted to answer the question: What effect has cold temperature on cattle grubs? The practical importance of knowing whether the early dropping grubs survive or not is evident. From one to three treatments with a rotenone spray or dust are given to cattle in the control of the grubs. Much time and money would be saved if the first treatment could be postponed and one of the other treatments eliminated. On the other hand if, in postponing the first treatment, a large number of grubs are left uncontrolled, the program would reasonably be only partially successful.

Several papers on the temperature and humidity relationships of *Hypoderma lineatum* have been published. Bishopp *et al.* (1926), in their work on the biology of cattle grubs, write that mature larvae and pupae can withstand rather low temperatures. The pupae appear to be more resistant to cold than the larvae. These workers found that a "good percentage of adults" emerged from pupae under observation when a minimum of −15.8° C. was reached. They also report a 55-per cent emergence from larvae and pupae exposed to −12.5° C. and a 68 per cent emergence from specimens exposed to −7.2 °C. Salt (1944) determined the undercooling points of larvae and pupae and found the means to be −23.4° C. and −23.6° C. respectively. Hadwen (1915) kept 13 pupae of *H. lineatum* in an incubator with intermittent heat up to 32° C. and recorded pupal periods of from 13 to 19 days. Bruce (1938) investigated the influence of moisture upon the development of pupae of *H. lineatum* and *H. bovis* into flies. He found that no flies of *H. lineatum* emerged from pupae which were buried one-fourth inch in soil holding 10 per cent or more of water. All pupae which were buried in soil with less than 5 per cent moisture developed into flies. Three flies emerged from the same number of pupae retained on a screen platform one-fourth inch above water. Snipes & Cooper (1942) have summarized the biology of cattle grubs in Wyoming.

The present paper has included the following studies on *Hypoderma lineatum:*

1. Development and survival of free larvae and pupae caged on native range vegetation.
2. Effects of low temperatures at various exposure times on the free larvae.
3. Development of free larvae and pupae at various constant temperatures.
4. Development of free larvae and pupae at various constant humidities.

EXPERIMENTAL PROCEDURES.—Larvae of *Hypoderma lineatum* were obtained for experimental use by placing cotton duck coats around infested dairy cows. The larvae on maturing crawled from the cysts in the backs and fell to the bottom of the coats. The grubs were gathered three times daily and were used immediately after each collection.

In the field tests at Laramie and at

Cheyenne, larvae were placed on native vegetation throughout the grub dropping season. A small screen cage was set over each grub as it was placed in the field. The cages were made of eighth-inch hardware cloth. The cages were 4 inches high and 3 inches in diameter. Maximum and minimum thermometers were laid on the ground surface near the cages and were read each morning and evening.

In the extreme low temperature experiments, larvae were retained individually for 2 hours at 15° C. after each collection in 1 by 6 inch pyrex test tubes which were stoppered about midway with a cotton plug. Before being half immersed in an alcohol bath for the tests, the tubes were tightly stoppered with rubber stoppers. The alcohol baths were maintained at temperatures of −5°, −10°, −15°, −20°, and −25° C. within ±0.3° C. The tubes with the grubs were left at these low temperatures for periods of 1, 4, or 8 hours. After exposure the larvae were observed and again placed at 15° C. and kept under observation until survival or death could be ascertained.

For studies on the effects of constant temperatures and humidities, larvae were confined individually in small bottles which were covered with wire screen. The bottles were placed in *Scheibler* desiccators having an inside diameter of 150 mm. Constant humidities were obtained by using the methods of Ludwig & Anderson (1942) as follows: for 0 per cent humidity, calcium chloride; for 32 per cent, a concentrated magnesium chloride solution; for 56 per cent, a concentrated sodium bromide solution; for 76 per cent, a concentrated sodium chloride solution; and for 100 per cent, distilled water. The desiccators containing the larvae were placed in temperature cabinets maintained at 15°, 20°, 25°, and 30° C. within ±0.3° C.

DEVELOPMENT OF *Hypoderma lineatum* ON NATIVE RANGE.—Larvae were placed on native range vegetation at Laramie and Cheyenne to observe development of *Hypoderma lineatum* under field conditions. In 1945, 24 larvae and pupae were set out at Cheyenne and 44 larvae at Laramie; in 1946, 44 larvae were set out at Laramie. The larvae were placed in the field during the normal dropping period at Cheyenne; however, at Laramie they were placed in the field as long as 18 days previous to the normal dropping period as well as during this period. The mature larvae were obtained early for planting at Laramie by bringing infested cows to this city from Virginia Dale, Colorado, where the season is 2 to 3 weeks advanced. The specimens at Cheyenne were set out from March 3 to March 31, 1945; and the specimens at Laramie from March 1 to April 16, 1945, and from February 25 to May 12, 1946.

For comparative purposes, the seasonal histories of the larval stage in the backs of cattle were observed in the two areas. Observations showed that the grubs dropped earlier at Cheyenne than at Laramie. At Cheyenne in 1945, grubs of *Hypoderma lineatum* first appeared in the backs of cattle January 10 and began to drop around February 24. The last grubs remaining in the backs of cattle at Cheyenne were found April 30. At Laramie, grubs first appeared in the backs of cattle February 2, 1944, and February 6, 1946. Grubs began to drop at Laramie around March 17, 1944, March 22, 1945, and March 14, 1946. The dates of the last grubs present in the backs were May 6, April 19, and May 12 for the years 1944, 1945, and 1946, respectively.

Table 1.—Emergence of flies from pupae of *Hypoderma lineatum* held under field conditions at Laramie, Wyoming.

Date of Planting	Minimum Ground Temperature to Which Exposed	Larvae Planted	Flies Emerging	Per Cent Emergence of Flies
March 1 to 5, 1945	−13° C.	15	12	80
March 11 to April 2, 1945	−11° C.	22	21	95
April 8 to 16, 1945	− 8° C.	7	7	100
Feb. 24 to March 2, 1946	−11° C.	14	14	100
March 14 to 19, 1946	− 5° C.	15	13	87
March 29 to 31, 1946	− 5° C.	8	8	100
April 10, 1946	− 5° C.	4	4	100
May 4 to 12, 1946	− 4° C.	3	3	100

The results of planting grubs in the two areas demonstrated that survival of the free larvae and pupae in nature is remarkably high. At Cheyenne 23 flies developed from 24 larvae and pupae set out. At Laramie 40 flies developed from 44 larvae set out in 1945 and 42 flies developed from 44 larvae set out in 1946. The data for Laramie are shown in table 1. The 27 larvae planted from March 14 to April 10, 1946 were collected from one Holstein cow which had an infestation of approximately 100 grubs. The first 15

grubs to drop from the cow were planted between March 14 and 19; the fifty-third to the sixtieth grubs to drop were planted between March 29 and 31; and the eighty-fourth to the eighty-seventh grubs to drop were planted on April 10.

All of the above data indicate a high survival of larvae and pupae in nature. Even when larvae were placed in the field up to 18 days in advance of the normal dropping season, survival was high. The minimum ground temperature to which any larvae were exposed during 2 seasons of planting at Laramie was −13° C. On exposure to this temperature, 80 per cent of the specimens survived and produced flies. Deaton & Frost (1941) have recorded no ground temperature lower than −13° C. after February 1 for Laramie during 3 years of study, 1937, 1938, and 1939. Evidently, little mortality of grubs occurs because of cold weather.

To know the cause of death of the four grubs which died in 1945 and of the two which died in 1946 would be of value in solving the problem of survival of cattle grubs at low temperatures under natural conditions. Although definite information is lacking, the following diagnosis suggests that low temperature was responsible for some of the deaths. Three of the larvae which died in 1945 were placed in the field when the ground was covered by a light snow. For the four following days minimum ground temperatures of −11°, −13°, −11°, and −10° C., respectively, were recorded. Since no pupation of the larvae occurred the indications are that death took place early, very likely during the time of the low minimum temperatures, as pupation of larvae has been found to take place usually within 1 to 3 days after dropping. Furthermore, in the low temperature tests to be described later, some larvae were frozen and killed on exposure to −10° C. Nine other larvae which were placed in the field at the same time and under the same conditions produced flies. This represents a survival rate of 75 per cent. In the laboratory tests, seven out of nine, or 78 per cent survived an exposure to −10° C. for 8 hours. The death of the fourth grub in 1945 is more difficult to analyze. The larva was placed in the field on March 11 and was exposed to a minimum ground temperature of −4.5° C. during the four succeeding days. The larva formed a puparium but on examination only a fatty mass was found within. The specimen died early but the cause was not evident.

In 1946 two of the larvae set out in the field died before reaching the adult stage. The two grubs were subjected to a minimum ground temperature of −5° C. Pupation occurred and two dead but well formed female flies were found within the puparia. Death obviously occurred late in the pupal stage and was probably caused by some factor other than low temperature. Later it will be shown that a number of pupae reared at constant temperatures of 20° and 25° C. reached the same stage of development.

The conditions of the ground at the time of setting the larvae out are noteworthy. In 1945 five larvae were placed on the surface of dry ground, 21 larvae on the surface of wet ground, and 11 larvae on snow. The numbers of flies to emerge from the three groups were 5 out of 5 larvae placed on dry ground, 20 out of 21 larvae placed on wet ground, and 8 out of 11 larvae placed on snow. In 1946, 22 larvae were set out on dry ground, 13 on wet ground, and 10 on snow. The numbers of flies that emerged were 22 flies from 22 larvae placed on dry ground, 12 flies from 13 larvae placed on wet ground, and 9 flies from 10 larvae placed on snow. Some of the larvae listed as being set out on wet ground were placed in the field during a drizzle which later turned to snow. The snow eventually covered them with a blanket a foot deep. The larvae listed on snow were either placed lightly on the surface or dropped from a height of approximately four feet to simulate the dropping from a cow. However, in either case, the larvae came to lie in snow pockets beneath the snow surface. Survival of larvae in snow, as previously noted, was high.

The time after dropping which is required by a larva to change to the characteristic form of the puparium was observed. In 1946, at Laramie, 25 larvae that dropped between March 16 and April 10 were watched closely. The time for transformation varied from 6 hours to 7 days and averaged 2.3 days. Three larvae changed to the pupal form the same day on which they had dropped from the cow; nine larvae completed metamorphosis the following day. In comparison, Bishopp *et al.* (1926) found that the

change to the typical form of the puparium occurred within 1 to 12 days and averaged 3.4 days. As one would expect, the rate of transformation showed a positive correlation with temperature. The mean daily ground temperature (mean of four average daily ground temperatures) at which seven larvae completed metamorphosis in 3 days was 3.8° C., whereas the mean daily ground temperature (mean of 2 average daily ground temperatures) at which nine larvae completed metamorphosis in 1 day was 12° C. The range of mean daily ground temperatures at which larvae transformed in 3 days was 2.9° to 5.1° C. and the range at which larvae transformed in 1 day was 10.8° to 12.9 ° C.

Information on the length of the period from the dropping of the grub to the emergence of the fly was obtained. Most of this period is occupied by the pupal stage but a short time is consumed by the free larval stage as was noted above. The period referred to in this paper as the pupal period includes the short free larval stage as well as the pupal stage.

At Laramie, in 1945, the pupal periods of 40 specimens ranged from 39 to 80 days and averaged 64 days; in 1946 the pupal periods of 39 specimens ranged from 34 to 80 days and averaged 53 days. These data include information on larvae which were placed in the field previous to the normal dropping period. Excluding the latter data, the pupal periods of 14 larvae placed in the field from March 28 to April 16, 1945 ranged from 39 to 57 days and averaged 48 days. In 1946 the pupal periods of 25 larvae placed in the field from March 14 to May 12 ranged from 34 to 60 days and averaged 46 days.

The pupal periods of specimens planted early in the season were longer than those planted late in the season. For example, the first 14 specimens planted in 1945 had an average pupal period of 74 days, while the last 14 had an average pupal period of 48 days. In 1946 the first 14 specimens planted had an average pupal period of 67 days, while the last 14 had an average pupal period of 42 days. The result of these differences in developmental rate is that the period of adult emergence is short in comparison with the period of the dropping of the grubs.

Information on the pupal period has been reported by Bishopp *et al.* (1926) for Texas and New York, by Hearle (1932) for Canada, and by Bruce (1938) for North Dakota. The average length of the period at Dallas, Texas, and in Canada was 42 days. The similarity of the mean length of the pupal period at decidedly different latitudes is not confirmed exactly by this study, but the close correspondence of all these data is no doubt due to the fact that the larvae drop earlier in the year in southern latitudes and later in northern.

The position of the pupa on the ground was recorded for 43 specimens that were placed in the field in 1946. Ten pupae rested on the surface of the ground without protection and ten rested in the same position but were afforded protection by vegetation. Twenty-three pupae were in shallow pits but had their dorsal surfaces exposed. Twelve of these were surrounded by vegetation, 11 were not. Survival was high among pupae in all positions described above.

Emergence of flies extended over a longer period in 1946 than in 1945. In 1945 emergence of flies at Laramie occurred from May 14 to May 25, while in 1946 emergence of flies occurred from April 30 to June 15. To some extent the increased spread of emergence dates in 1946 was the result of placing larvae in the field over a longer period. As has been mentioned previously, larvae were placed in the field at Laramie from February 24 to May 12, 1946, and from March 1 to April 16, 1945. Some of the differences in spread, however, were probably due to differences in weather. In 1946 an unusually warm and dry April promoted development of the pupae which resulted in the emergence of some flies on April 30. May was colder and wetter than usual and no doubt extended the pupal period of larvae dropped during this month. The climatological data recorded for Laramie by the Weather Bureau were: April, 1946 mean temperature, 46.4° F., (departure from the normal, +8.3°) precipitation 0.53 inches (departure from the normal −0.76 inches); May, 1946 mean temperature, 43.6° F. (departure from the normal, −3.9°), precipitation, 3.30 inches (departure from the normal +1.86 inches). On the other hand, in 1945, April was colder than normal and May warmer and drier. The mean temperature for April was 31.8° F. (departure from the normal −6.4°) and for May

48.4° F. (departure from the normal +1.0°). These climatological conditions were apparently the cause of later emergence of flies in 1945.

The length of life of adults under caged conditions in the field varied from 12 hours to 11 days. In 1945 the average length of life of 33 individuals was 2.3 days and in 1946, the average length of life of 29 individuals was 4.7 days.

EXPOSURE TO LOW TEMPERATURES.—A number of larvae of *Hypoderma lineatum* were exposed to different low temperatures ranging from −5° C. to −25° C. for 1-, 4-, or 8-hour periods. Table 2 shows the results of the tests. All larvae subjected to −25° C. died, while all subjected to −5° C. survived. Larvae subjected to intermediate temperatures, that is to temperatures of −10° C., −15° C., or −20° C., showed a progressive increase in mortality as the temperature was lowered. For any of the given temperatures mortality was in general greatest among the larvae exposed for the longest time. None of the larvae which survived exposure to low temperatures were frozen by the treatments, but all which were frozen hard were killed. Some of the larvae which were not frozen by exposure to −20° C. were nevertheless killed.

Table 2.—Survival and death of larvae of *Hypoderma lineatum* exposed to low temperatures.

Hours of Exposure	Exposure Temperatures				
	−5° C.	−10° C.	−15° C.	−20° C.	−25° C.
1—Survived	—	2	8	5	0
Killed	—	0	1	5	2
4—Survived	—	2	4	5	0
Killed	—	0	3	5	1
8—Survived	15	7	7	1	0
Killed	0	2	3	5	3

Fourteen of the 15 larvae which were exposed in a dry state to −5° C. were afterwards seeded with 1 to 2 drops of water and again exposed to −5° C. Under these conditions 9 were frozen hard and killed, 5 remained soft and survived.

The data indicate that the freezing point of the free larvae of *Hypoderma lineatum* is around −5° C. or higher, that is, somewhere between −5° C. and 0°. The fact that larvae could be frozen and killed at −5° C. when seeded with water is significant. Under certain field conditions, such as rain followed by sudden drop in temperature or thawing of snow and subsequent freezing, the death of larvae could occur at temperatures not much below 0° C. However, larvae can usually withstand colder temperatures without freezing, as the survival of various numbers of individuals exposed to −10° C., −15° C., and −20° C. has indicated. This is possible probably because of undercooling, a process which Salt (1936) has discussed in relation to the freezing of insects. In a recent paper the same author has given the range of undercooling points of dry larvae of *H. lineatum* as −19.8° to −24.7° C. and of wet larvae as −17.7° to −27.7° C. The assumption was then made that the undercooling range, −17.7° to −27.7° C., was the lethal temperature range for dropped larvae. Since we have frozen and killed 2 out of 9 larvae on subjecting them to −10° C. for 8 hours and 9 out of 14 larvae on subjecting them in a wet condition to −5° C. for 8 hours and less, lethal temperatures evidently range much higher than −17.7° C. Results such as these demonstrate the necessity of studying the time of action of cold temperature as well as the external temperature or surface temperature to which the insect is momentarily subjected.

Without going into the theories of death by cold temperature, which subject has been thoroughly reviewed by Luyet & Gehenio (1940), we should note again that the death of larvae of *Hypoderma lineatum* occurred with and without the internal formation of ice. Our data show that death always attends the freezing of a larva. Death is not due here to the attainment of a minimal temperature, since larvae which could be frozen by inoculation with a drop of water were killed at −5° C. while other larvae which remained unfrozen withstood temperatures of −10°, −15°, and some −20° C. A few larvae which were exposed to −20° C. were killed without formation of ice. Three out of five were killed in this way on exposure for 4 hours and two out of three on exposure for 8 hours. Death of larvae of *H. lineatum* thus sometimes occurs when they are in the subcooled state. Even though the number dying in this state was small, the fact that some died indicates that the undercooling point is not an absolute criterion of cold tolerance for *H. lineatum*.

DEVELOPMENT OF PUPAE AT CONSTANT TEMPERATURES.—The length of the pupal period and the survival rate of *Hypoderma lineatum* held at constant temperatures were determined. Table 3 shows the length of the pupal period and table 4 the survival rate. Constant temperatures of 15°, 20°, 25°, and 30° C. were employed along with a relative humidity of 76 per cent. This degree of humidity is a favorable one for the development of *H. lineatum* pupae as will be shown later. The mean length of the pupal period of specimens retained at 15° C. was 43.8 days, at 20° C., 19.8 days, and at 25° C., 12 days.

The survival of pupae was greatest at 20° C. At this temperature, 81 per cent of the pupae produced flies. At 15° C. there was a 44 per cent emergence and at 25° C., a 33 per cent emergence. At 30° C. no flies emerged. Many puparia from which there was no emergence contained dead flies.

Table 3.—Length of pupal period of *Hypoderma lineatum* at 76 per cent relative humidity and at different constant temperatures.

Temperature ° C.	Number Specimens	Mean Length Pupal Period Days	Range Pupal Period— Days
15	4	43.8	40 to 47
20	21	19.8	17 to 22
25	4	12.0	all 12

Table 4.—Survival of pupae of *Hypoderma lineatum* at 76 per cent relative humidity and at different constant temperatures.

Temperature ° C.	Flies Emerged	Flies Not Emerging	Total	Per Cent Emergence
15	4	5	9	44
20	21	5	26	81
25	4	8	12	33
30	0	7	7	0

Dead flies were found in 4 out of 5 puparia retained at 15° C.; 4 out of 5 retained at 20° C.; 6 out of 6 retained at 25° C.; and 2 out of 7 retained at 30° C. Most pupae evidently died late in the pupal stage, except those reared at 30° C. The high temperature of 30° C. probably killed the majority of pupae before development progressed very far for only fatty masses were found within most of the puparia. Seven larvae were placed at a constant temperature of 30° C. and 0 per cent relative humidity. None of these produced a fly. Six transformed to the pupal stage but only fatty masses were found later within the puparia. One died in the free larval stage.

DEVELOPMENT OF PUPAE AT CONSTANT HUMIDITIES.—The length of the pupal period and the survival rate of *Hypoderma lineatum* pupae held at five different relative humidities and at temperatures of 20° and 25° C. were studied. Very little difference was found in the length of the pupal period and in the survival rate of pupae reared at relative humidities ranging from 0 to 76 per cent. At 100 per cent the pupal period was slightly lengthened and mortality of pupae was greatly increased. These data are shown in tables 5, 6, 7 and 8.

That mortality of pupae is great at high humidities has been previously shown by Bruce (1938) in his paper on soil moisture and its relation to the mortality of *Hypoderma* pupae.

SUMMARY.—A study of the effects of temperature and relative humidity on the development of free larvae and pupae of *Hypoderma lineatum* (De Villers) was made under both field and controlled laboratory conditions. A high survival rate of pupae was found to obtain under field conditions, even when larvae were placed in the field up to 18 days before the normal dropping period.

Table 5.—Length of pupal period of *Hypoderma lineatum* held at constant temperatures of 20° and 25° C. and at different relative humidities.

Relative Humidity	Number Specimens	Mean Length Pupal Period Days	Range Days
	Temperature 20° C.		
0	16	20.1	18–22
32	5	18.6	18–19
56	2	18.5	18–19
76	21	19.8	17–22
100	5	21.4	20–22
	Temperature 25° C.		
0	4	11.5	11–12
32	4	11.5	11–12
56	3	11.7	11–12
76	4	12.0	12
100	1	14.0	14

Table 6.—Survival of *Hypoderma lineatum* pupae held at constant temperatures, of 20° and 25° C. and at different relative humidities.

Relative Humidity	Flies Emerged	Flies Not Emerging	Total	Per Cent Emergence
Temperature 20° C.				
0	16	4	20	80
32	5	3	8	63
56	2	1	3	67
76	21	5	26	81
100	5	9	14	36
Temperature 25° C.				
0	4	9	13	31
32	4	8	12	33
56	3	9	12	25
76	4	8	12	33
100	1	11	12	8

Low temperature tests showed that some larvae survive a temperature of −20° C. but none survive a temperature of −25° C. A group of larvae was seeded with water and a high percentage of these were frozen and killed when subjected to −5° C.

Pupae were reared at constant temperatures of 15°, 20°, 25°, and 30° C. The survival rate of pupae reared at 15° C. was 44 per cent; at 20° C., 81 per cent; at 25° C., 33 per cent; and at 30° C., 0 per cent. The length of the pupal period was 43.8 days at 15° C., 19.8 days at 20° C., and 12.0 days at 25° C.

Two groups of pupae were reared at constant relative humidities of 0, 32, 56, 76 and 100 per cent, one group at a temperature of 20° C. and one at 25° C. Very little difference was found in the length of the pupal period and in the survival rate of pupae reared at relative humidities ranging from 0 to 76 per cent. At 100 per cent relative humidity the pupal period was slightly lengthened and mortality of pupae was greatly increased.

The conclusion was reached that little aid in control of grubs can be expected in Wyoming from inclement weather during the dropping period. Although grubs which were seeded with water have been killed in the laboratory by temperatures as high as −5° C., the majority of larvae in a dry condition survived a temperature of −15° C. Ground temperatures have been shown not to fall below −13° C. after February 1 at Laramie for the several years in which data have been taken. The period beginning February 1 and thereafter includes the dropping periods at Cheyenne and Laramie and probably at all other sections of Wyoming as well.—1-2-47.

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DDT to Control the Gulf Coast Tick

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The Gulf Coast tick, *Amblyomma maculatum* Koch, is a serious enemy of livestock in the region bordering the Gulf of Mexico. In general it does not become sufficiently abundant to be of economic importance in areas more than 100 miles inland. Specimens have been seen from all the Gulf Coast States, from Georgia and South Carolina, and from Mexico. The tick is also reported from Central and South America. It is a three-host tick (Hixson 1940). The immature stages are found on birds and small mammals, whereas the adults attack cattle, horses, sheep, goats, hogs, deer, and man. Generally they attach to the outer ear, usually near the tip. At times they attach around the base of the horns and on the eyelids. Frequently they are found under the back of the hump on Brahma bulls. On horses they often attach in the mane and foretop, where they produce troublesome sores.

NATURE OF INJURY.—When the ticks attach to the ears of livestock, they cause the ears to swell and exude a yellowish serum, which dries and forms a hard scab or crust. Often this scab is as much as a quarter-inch thick and the ticks are almost totally encased in it. In severe cases the ears become greatly swollen and crack open. Such cases usually result in permanent malformation. However, by far the greatest loss is caused by the tick predisposing animals to attack by the screwworm fly, *Cochliomyia americana* C. & P. In some seasons 80 per cent of the screwworm cases in regions where the Gulf Coast tick is abundant are the direct result of tick injury. Many animals die as the result of these injuries, but even greater loss is caused by reduction in weight and impairment of their condition and the expenditure of time required to look after and treat injured animals. In Texas the period of severe tick injury usually starts in July and continues till about mid-October.

PASTURE MOWING AND TICK CONTROL.—There is a belief among certain ranchmen in the coastal area that systematic mowing of pastures to prevent rank growth of weeds and coarse grass aids in the control of the Gulf Coast tick. No detailed studies have been conducted along this line, but some observations were made that tend to bear out the belief.

Several pastures where a systematic program of mowing was in practice were observed during the period 1942 to 1945. The tick populations in these pastures were consistently low, whereas in adjoining unmowed pastures they were high. A typical example is given by pastures A and B observed in 1944. The two pastures were similar in every respect except that pasture A had been systematically mowed for

Table 1.—Results of tests with various preparations containing DDT for the control of Gulf Coast tick.

Date	Treatment		Number of Cattle	Average Number of Ticks per Ear				
	Stock No.	Per cent DDT		At Initial Examination	Weeks after Treatment			
					2	3	4	6
1943	1025	2	170	5.5	2.4	—	2.9	—
	1026	5	45	8.1	.4	—	.5	—
	None	—	32	5.4	5.5	—	7.7	—
1944	1036	5	592	4.5	.5	—	1.85	—
			778	4.6	.2	—	—	—
	None	—	40	4.5	14.0	—	—	—
1945	1037	5	948	6.4	—	1.5[1]	—	.3
			1510	6.4	—	—	2.7[1]	.4[2]
			822	5.0	—	—	—	.2
	None	—	25	5.0	—	15.2	—	—

[1] All cattle were given a second treatment.
[2] This examination was made 7 weeks after the initial treatment.

the past several years. The cattle in the two pastures were similar. On August 8 the cattle in pasture A had an average of 0.47 tick per ear as compared with 4.5 ticks per ear on the cattle in pasture B. On September 20 the cattle in pasture A had an average of 0.17 tick per ear and those in pasture B had 5.1 ticks per ear. Although these observations are not conclusive, they indicate that systematic mowing of pastures may play an important role in the control of the Gulf Coast tick.

EXPERIMENTS WITH LIVESTOCK.—Experiments were conducted during the period 1942 to 1945, inclusive, to develop a remedy that would kill the Gulf Coast tick and give a satisfactory period of protection from reinfestation. This work was made possible by the cooperation of a group of ranchmen in Jackson, Calhoun, and Matagorda Counties, Tex., who furnished their herds and ranch facilities for the tests. In 1942 only preliminary tests were conducted with various chemicals to determine their toxicity to the Gulf Coast tick. These tests failed to reveal any chemical with outstanding possibilities.

Treatment of Cattle.—From 1943 through 1945 tests were made on cattle with various preparations containing DDT, and the results of these tests are shown in table 1.

In 1943 stock 1025, a 2-per cent DDT mixture, gave a good reduction in the number of ticks present, but was not so effective as a 5-per cent DDT mixture designated as stock 1026. These stocks were made by adding DDT to adhesive mixtures composed of rosin, hydrogenated methyl abietate, dibutyl phthalate, and benzene. Difficulty was experienced with both stocks 1025 and 1026, as they appeared to be too thin, and consequently did not remain on the ears satisfactorily during the hot weather. In an attempt to overcome this difficulty stock 1036 was prepared. It contained 5 per cent of DDT, an increased amount of rosin and dibutyl phthalate, slightly less of the methyl abietate[1] and no benzene. This stock was tested in 1944 and found to be too thick for easy application. However, it gave good initial kill and a satisfactory period of protection from reinfestation. In 1945 stock 1037, containing less rosin and more of the methyl abietate[1] was prepared and tested. The consistency of this stock proved to be satisfactory for conditions in southern Texas.

The tests with stock 1036 demonstrated clearly the ability of the preparation to kill the ticks and to provide a satisfactory period of protection from reinfestation, but the tick population in 1944 was only medium heavy, and there was some doubt as to its effectiveness under more adverse conditions.

In 1945 conditions were adverse from the start of tests. The ticks appeared 2 to 3 weeks earlier than normal and the population was extremely heavy. A hurricane accompanied by 30 inches of rainfall occurred in the middle of the tick season. Stock 1037 gave good initial kill of ticks and provided 3 to 6 weeks protection from serious reinfestation. Only 33 cases of screwworms as a result of tick injury occurred in 3,280 head of cattle, whereas in 25 head of check animals where no treatment was given there were 9 cases of screwworms.

In another series of tests 8000 head of mixed cattle were treated by ranchmen using stock 1037. Although no tick counts were made, the ranchmen reported a good reduction in ticks on the animals and few cases of screwworms as a result of tick injury.

Treatment of Sheep.—A flock of 73 sheep was treated with stock 1037. It was estimated that the sheep had an average of 8 ticks per ear at the time of treatment. Four weeks after treatment ticks were found on only 4 of these sheep; 1 sheep had 5 ticks, and 3 had 1 tick each.

Treatment of Horses.—Thirty-two horses were treated with stock 1036. At the time of treatment they had an average of 3.1 ticks per ear. Two weeks later they had an average of 0.5 tick per ear. Six check animals had an average of 3 ticks per ear at the time of the first examination and 5 ticks per ear 2 weeks later. In some cases this material caused the hair to shed from the ears and there was some indication of skin injury. For this reason it appears that stock 1036 is not suitable for use on horses.

METHOD OF USING STOCK 1037.—From the results of these experiments it appears that, when properly used, stock 1037 will kill the Gulf Coast tick and prevent reinfestation of cattle or sheep for 3 to 6 weeks. For best results the treatment should be applied to the ears of these ani-

mals as soon as ticks begin to be numerous. A second application should be made when ticks again begin to attach to the animals.

The material should be liberally applied to both the inside and outside of the outer ears and around the base of the horns. It is best applied with the bare hands and should be rubbed well into the hair and skin. The material is not injurious to the hands. It can be removed readily by washing the hands in benzene, white gasoline, or kerosene and immediately thereafter washing with soap and water. One gallon of stock 1037 will treat 125 to 150 head of cattle.

PREPARING STOCK 1037.—Stock 1037 is composed of 5 per cent (by weight) of DDT (technical), 47 per cent of rosin, 33 per cent of a hydrogenated methyl abietate[1] and 15 per cent of dibutyl phthalate.

To prepare stock 1037 place the DDT and dibutyl phthalate together and stir or shake until the DDT is in solution. In another container place the rosin and methyl abietate and heat slowly until the rosin is thoroughly liquefied, stirring frequently to prevent scorching. When the rosin is thoroughly liquefied, remove from the heat and allow the mixture to cool. When the temperature is 125° F. or below, add the dibutyl phthalate and DDT and stir until uniformly mixed. As soon as the mixture has cooled it is ready for use.—12-18-46

[1] *Hercolyn.*

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DDT to Control Wood Ticks

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The term "wood tick" is generally used by the public to apply to any species of tick encountered in woods or fields, particularly to those attacking man. In the East the species most often called wood ticks are the American dog tick, *Dermacentor variabilis* (Say), the lone star tick, *Amblyomma americanum* (L.), and the black-legged tick, *Ixodes scapularis* Say. In previous papers (1944 and 1945) the authors reported encouraging results with DDT for the control of these species in small plots. Further experiments on a larger scale have confirmed the earlier observations and have given additional information on the dosage required for effective control.

EXPERIMENTS AGAINST THE AMERICAN DOG TICK.—Three experiments with DDT for the control of adults of the American dog tick were conducted on the island of Martha's Vineyard, Mass. In previous experiments effective control had been obtained in small plots at rates of 9, 7, and 3 pounds of DDT[1] per acre. As the heaviest infestations of this species are usually found along roadsides and paths, roadside strips were used as test plots. Each plot was 1 acre in area, usually 4,356 feet long by 10 feet wide. Such plots are quite liable to reinfestation from adjacent fields. The abundance of ticks in the plots was determined before and after treatment by dragging a sheet of white flannel 1 yard wide by 1.5 yards long along the entire length of each plot. Ticks were counted, removed from the drag, and returned to the vegetation at intervals of approximately 100 paces.

Two types of emulsion were used, one containing 5 pints of soluble pine oil[2] per pound of DDT, and the other containing 40 fluid ounces of xylene and 8 fluid ounces of *Triton X-100* (an aralkyl polyether alcohol) per pound of DDT. The materials were applied at 1, 1.5, 2, or 2.5 pounds of DDT per acre, but in all cases 100 gallons of spray was used per acre. The applications were made with a gasoline-powered sprayer operating at a pressure of 150 pounds per square inch.

The results of the three experiments are summarized in table 1. A series of six tests in one locality (Chilmark) gave highly

[1] Throughout this paper DDT refers to the technical grade.

[2] A commercial grade with a specific gravity of 0.950–0.960 at 15.5° C., containing not more than 10 per cent of water and not less than 80 per cent of destructively distilled pine oil, together with an emulsifier.

Table 1.—Abundance of American dog ticks in roadside plots following treatment with DDT emulsions. Tests on Martha's Vineyard, June 1945.

Treatment and Dosage of DDT (Pounds per Acre)	Number of Ticks Before Treatment	Date Sprayed	Date of Collection	Per Cent of Original Infestation
Tests at Chilmark				
Pine oil emulsion				
2.5	225	June 9	June 7	100
			11	1
			14	4
			22	4
			30	4
	214	21	20	100
			25	1
			28	0
			July 1	3
2	96	9	June 7	100
			11	2
			15	2
			22	8
			30	7
Xylene emulsion				
2.5	686	13	11	100
			15	7
			21	3
			28	4
2	146	13	11	100
			15	4
			21	0
			28	5
1.5	421	19	19	100
			21	5
			26	6
			29	5
Check (no treatment)	63	—	11	100
			14	183
			21	186
			25	224
			28	210
			July 1	205
Tests at Gay Head				
Pine oil emulsion				
2	388	June 5	June 2	100
			7	2
			12	17
			19	26
			26	18
			29	23
	270	6	4	100
			8	6
			13	6
			20	10
			30	45
	156	6	6	100
			8	10
			13	27
			20	57
			30	69
1	551	5	2	100
			7	3
			12	26
			19	40
			26	32
			29	29
	231	6	4	100
			8	74
			13	67
			20	78
			30	97
	177	6	6	100
			8	81
			13	73
			20	82
			30	137

Table 1.—(continued)

Treatment and Dosage of DDT (Pounds per Acre)	Number of Ticks Before Treatment	Date Sprayed	Date of Collection	Per Cent of Original Infestation
Check (no treatment)	84	—	4	100
			7	92
			12	319
			19	268
			26	206
			29	219
Tests at Vineyard Haven and Oak Bluffs				
Xylene emulsion				
2	299	June 14	June 13	100
			16	4
			21	2
			28	2
1	389	14	14	100
			16	12
			21	6
			28	6
	330	16	15	100
			18	9
			22	10
			29	8

satisfactory control at dosages of 1.5, 2, and 2.5 pounds of DDT per acre. In all plots the abundance of ticks was less than 9 per cent of the original abundance for the period of observation, 10 to 22 days, whereas in the untreated plot abundance rose to 224 per cent during the same period. Pine oil and xylene emulsions were equally effective.

The results of six similar tests in a second locality (Gay Head) were less satisfactory. However, abundance was substantially lower in all treated plots than in the untreated one and in general was lower at a dosage of 2 pounds of DDT per acre than at 1 pound per acre. It is not entirely clear why better control was obtained at Chilmark at 1.5 and 2 pounds per acre than at 2 pounds per acre at Gay Head. It was probably due in part to a greater movement of ticks into the experimental plots at Gay Head, as indicated by the relative increase in abundance in the untreated plots in the two localities.

In three other tests in scattered localities on Martha's Vineyard (Vineyard Haven and Oak Bluffs) control was good at dosages of 1 and 2 pounds of DDT per acre.

On the basis of the foregoing tests it appears that the dosage of DDT required to insure effective control in every instance would be in excess of 2 pounds, but probably not more than 3 pounds, per acre.

EXPERIMENTS AGAINST THE LONE STAR TICK.—In previous experiments in small woodland plots the authors found that a dosage of 1 pound of DDT per acre would control nymphs and adults of the lone star tick. The following experiments were made to determine the duration of the residual effect of DDT and the relative effectiveness of different methods of application. The 1-pound dosage was used in all experiments, and was applied with a gasoline-powered sprayer operating at pressures of 150 to 350 pounds per square inch. Test plots of 0.5 or 1 acre were selected in woodland areas near Savannah, Ga. The abundance of ticks in each plot was measured before and after treatment by collecting with a flannel drag. Ticks were removed from the drag and returned to the vegetation every 100 feet. Each plot was crossed along 10 parallel lines 20 feet apart.

To test the maximum period of protection, an experiment was begun in March, so early in the season that only a few ticks had become active. The disadvantage of such an early beginning is that it is impossible to forecast how heavy later infestations in the locality will be. In this locality they did not become heavy. A 1-acre plot was sprayed on March 20 with 1 pound of DDT dissolved in 5 pints of soluble pine oil and emulsified in 100 gallons of water; a similar plot was left untreated. Control in the sprayed plot was very satisfactory throughout the period of observation, 87 days, as nymphal abundance did not exceed 15 per cent of the original and adults never reappeared, whereas in the check plot nymphal abundance rose to 350 per cent and adult abundance to 266 per cent of the original.

Table 2 presents the results of an experiment to determine whether a smaller amount of a more concentrated spray could be used without reducing the effectiveness of the treatment. Two 1-acre plots were sprayed, one on March 26 with 1 pound of DDT and 5 pints of soluble pine oil in 50 gallons of water, and the other on March 24 with the same amount of DDT and pine oil in 100 gallons of water. Control was about as satisfactory as in the preceding test. In the sprayed plots nymphal abundance once rose to 22 and 75 per cent of the original, but dropped shortly thereafter, whereas in the untreated check area it rose to 812 per cent of the original. Adult abundance in the sprayed areas once reached 100 and 150 per cent of the original, while in the check area it reached 700 per cent. Although ticks in the sprayed plots were more numerous than in the previous test, they were also much more numerous in the check. During most of the 125 days of observation the treatments held the tick infestation in the sprayed plots to less than the original low abundance of March, while in the check plot it was increasing to the normal high abundance of May and June. The fact that it rose and fell in the sprayed plots while rising steadily in the check indicates that, although newly active ticks were appearing in all plots, the residual action of the DDT was killing them in the sprayed ones. There was no great difference in effectiveness between the 50- and 100-gallon treatments, the latter appearing slightly better agains-

Table 2.—Per cent of original infestation of lone star ticks in 1-acre woodland plots following treatment with two concentrations of DDT in pine oil spray. Savannah, Ga., 1945.

Collection Date	1 Pound of DDT in 100 Gallons of Spray Applied March 24		1 Pound of DDT in 50 Gallons of Spray Applied March 26		Check, No Treatment	
	Nymphs (36)[1]	Adults (4)	Nymphs (16)	Adults (8)	Nymphs (25)	Adults (6)
March 26	11	25			232	250
28	—	—	13	0	—	—
April 2	22	150	75	100	464	317
12	6	25	38	66	556	483
20	6	75	38	0	812	683
May 5	3	75	6	0	812	650
June 16	6	50	0	0	604	700
July 27	17	0	88	66	320	33

[1] Figures in parentheses indicate numbers of ticks collected a few days before spraying.

nymphs and the former slightly better against adults. By June 16 clusters of larvae were beginning to appear in the treated and check plots.

Two experiments were made to compare the effectiveness under field conditions of sprays using three different solvents—pine oil, xylene, and *Velsicol AR-60* (chiefly di- and tri-methylnaphthalenes). In the first experiment the treatments were applied in April, when tick abundance was approaching its peak, to three half-acre plots. Two plots were sprayed with emulsions containing 8 ounces of DDT in 50 gallons of water, but one was made with 40 ounces of soluble pine oil and the other with 20 ounces of xylene and 4 ounces of *Triton X-100*. The third plot was left untreated.

In the second experiment three sprays, and also a 10 per cent DDT-pyrophyllite dust, were applied in May to half-acre plots. All the sprays contained 8 ounces of DDT per 50 gallons; the formulas for the DDT-pine oil and DDT-xylene sprays were the same as in the preceding test, but the third spray contained 32 ounces of *Velsicol AR-60* and 6 ounces of *Triton X-100* as emulsifier.

The results of both experiments are shown in table 3. In the first series of tests (treated April 11) a high degree of control was obtained in both treated plots throughout the period of observation, 107 days. The pine oil emulsion gave slightly better results than the xylene emulsion. In the second series (treated May 1) all treatments were satisfactory for the 87 days of observation, although against nymphs the dust was not quite so effective as the sprays.

The season of larval activity began early in June and clusters of live larvae were found in the treated as well as the untreated plots.

Airplane Spraying.—In 1946[1] experiments on airplane application of DDT sprays were conducted at Bull's Island, S. C., with the cooperation of the Fish and Wildlife Service, U. S. Department of the Interior. Moderate control of the lone star tick was obtained. The area where the sprays were applied was a coastal island with a heavy cover of palmettos, pines, oaks, magnolias, and much underbrush. The foliage was as thick as that of most tick habitats in the region, providing conditions of average difficulty for penetration of the canopy by the spray. The sprays were dispersed through spray bars under the wings. The plots were marked off by flags mounted on 35-foot bamboo poles set in the tops of the tallest pine trees at all corners of each plot.

Six plots (A, B, C, E, F, G) ranging from 18 to 29 acres in area were sprayed by airplane, and a 26-acre plot (D) was left untreated as a check. A 1-acre plot (H) was sprayed from the ground as an additional check on the effectiveness of the airplane spraying, and a second 1-acre plot (I) was left untreated as a check on the ground application.

[1] The treatments were applied by Frank Faulkner, of the Bureau of Entomology and Plant Quarantine, using an N3N-3 plane.

Table 3.—Comparative effectiveness of DDT sprays containing different solvents and a dust on lone star ticks in woodland plots. Dosage 1 pound of DDT per acre. Savannah, Ga., 1945.

Treatment	Number of Ticks Before Treatment		Date of Collection	Per Cent of Original Infestation	
	Nymphs	Adults		Nymphs	Adults
Treatments applied on April 11					
Pine oil spray	94	10	April 9	100	100
			12	4	0
			20	1	0
			May 5	0	0
			June 15	2	0
			July 27	1	10
Xylene spray	44	10	April 9	100	100
			12	16	30
			20	5	0
			May 5	2	10
			June 15	11	0
			July 27	9	0
Check (no treatment)	64	1	April 9	100	100
			12	107	900
			20	103	600
			May 5	114	1500
			June 15	64	500
			July 27	97	400
Treatments applied on May 1					
Pine oil spray	123	22	April 28	100	100
			May 2	2	5
			14	0	0
			June 19	0	5
			July 27	2	0
Xylene spray	112	15	April 28	100	100
			May 2	2	0
			14	3	0
			June 19	0	0
			27	2	0
Velsicol AR-60 spray	47	12	April 28	100	100
			May 2	6	0
			14	2	0
			June 19	2	0
			July 27	0	0
Pyrophyllite dust	42	6	April 28	100	100
			May 2	14	0
			14	7	0
			June 19	10	0
			July 27	12	0
Check (no treatment)	83	13	April 28	100	100
			May 2	95	123
			14	132	223
			June 19	70	38
			July 27	35	8

Table 4.—Abundance of lone star ticks in woodland plots following treatments with DDT. Except as noted, all plots were sprayed by airplane. Bull's Island, S. C., 1946.

Plot	Formulation[1] DDT	Accessory Material	Dosage of DDT (Pounds per Acre)		Number of Ticks Before Treatment Nymphs	Adults	Date Sprayed	Date of Collection	Per Cent of Original Infestation Nymphs	Adults
B	16.7	Soluble pine oil	83.3	3	801	200	April 19	April 16	100	100
								21	46	35
								May 6	25	34
								June 5	11	16
E	8.3	Soluble pine oil	41.7	3	1,186	282	22	April 19	100	100
								23	60	41
								May 8	24	24
								June 6	5	12
A	12.5	Xylene 32.5+*Triton X-100*	5	3	1,524	305	19	April 16	100	100
								21	40	35
								May 6	28	34
								June 5	12	12
F	8.3	Xylene 21.7+*Triton X-100*	3.3	3	1,933	293	22	April 20	100	100
								23	72	61
								May 7	26	27
								June 6	11	12
C	12.5	Xylene 32.5+*Triton X-100*	5	2	1,314	381	18	April 16	100	100
								20	81	69
								May 8	50	41
								June 5	28	21
G	6.3	Xylene 16.2+*Triton X-100*	2.5	2	1,081	392	April 22	April 20	100	100
								23	56	32
								May 8	6	17
								June 5	9	14
D		Check (no treatment)			1,541	608	—	April 18	100	100
								21–23	104	131
								May 7	102	148
								June 6	122	127
Road between A and B		Overlap of treatments of plots A and B			375	245	19	April 16	100	100
								21	26	17
								May 6	2	8
								June 5	3	2
Road between A and E		Overlap of treatments of plots A and E			425	163	19–22	April 16	100	100
								21	30	30
								May 6	2	13
								June 5	0.9	1
H[2]	0.1	Soluble pine oil	0.5	1	347	168	22	April 22	100	100
								23	16	8
								May 9	2	2
								June 6	2	5
I		Check (no treatment)			494	212	—	April 23	100	100
								May 9	91	97
								June 6	101	89

[1] Except in plot B, all materials are emulsions and figures represent percentages in water. In plot B the DDT was in solution in soluble pine oil. [2] Sprayed from the ground.

The abundance of ticks in the plots was measured by making collections with a drag. In each of the larger plots three complete crossings were made along parallel lines. The crossings were far enough from the boundaries of the plot to avoid areas that might have received an extra heavy treatment, as in the case of a common boundary between two plots, or an extra light treatment, as might have occurred on the windward boundaries of some plots. About every 100 paces the ticks were removed from the drags, counted, recorded, and returned to the ground. In the 1-acre plots 14 crossings were made.

The treatments applied to the plots and the abundance of ticks before and after treatment are listed in table 4. The airplane applications were less effective than the ground treatment. Reductions in tick abundance developed more slowly, but after 6 weeks control was about 85 per cent complete in most of the plots.

All the plots treated by airplane showed about the same degree of control except plot C, which was sprayed under less favorable wind conditions than the other plots and received only 2 pounds of DDT per acre, a smaller dosage than four of the other five plots received. Plot G, which also received only 2 pounds of DDT per acre, showed at least as good control as the plots receiving 3 pounds per acre, but the cover was not so dense as in the other

plots. The four plots receiving 3 pounds of DDT per acre showed no important difference whether the spray was concentrated or diluted.

Along a road which formed the common boundary of plots A and B and plots A and E the abundance of ticks was reduced to a degree comparable to that obtained in ground applications. Since the road was a common boundary, it was sprayed twice, once at the treatment of each of the adjacent plots, and thus received a dosage of about 6 pounds of DDT per acre. In addition the cover over the road, though complete, was less dense than in the plots.

The season of larval activity began early in June and clusters of live larvae were found in the treated as well as the untreated plots.

EXPERIMENTS AGAINST THE BLACK-LEGGED TICK.—The adults of the black-legged tick, like those of the American dog tick, concentrate on the sides of roads and paths that traverse the infested areas. Therefore, the experimental plots used in these tests were strips 30 feet wide, with a road down the center. They ranged in area from 0.67 to 1.2 acre. The treated plots were sprayed with an emulsion containing 12.8 ounces of DDT and 4 pints of soluble pine oil per 100 gallons of water.

Tick abundance in the untreated plots did not follow the trend of previous years, but reached a peak early in the season and declined rather than increased through January and February, a condition more than normally favorable to the success of the spray. The first spray was applied on December 19, at the rate of 17 ounces of DDT per acre. Tick abundance in the treated plot immediately dropped to 11 per cent of the original abundance, and after December 27 no ticks were found throughout the remainder of the period of observation, 102 days. During the same period the abundance of ticks in an untreated plot ranged from 35 to 150 per cent of the original.

A plot was treated January 8 with 16 ounces of DDT per acre and another was treated January 28 with 15 ounces of DDT per acre. In both plots the reduction of ticks was immediate, and only a single tick was found in each plot during the periods of observation, 82 and 39 days, respectively. During the same periods abundance in the untreated plots ranged from 5 to 106 per cent and from 35 to 81 per cent.

SUMMARY.—Experiments on the effectiveness of DDT for the control of the American dog tick, *Dermacentor variabilis* (Say), were made in roadside plots 1 acre in area. At a dosage of 2.5 pounds of DDT per acre control was uniformly satisfactory; at 1 to 2 pounds per acre control was satisfactory in some plots but not in others. Apparently the dosage required to insure effective control in every instance would be in excess of 2 pounds, but probably not more than 3 pounds of DDT per acre.

In woodland plots 0.5 to 1 acre in area nymphs and adults of the lone star tick, *Amblyomma americanum* (L.), were controlled throughout the season of activity, as long as 125 days, with 1 pound of DDT per acre. This dosage was effective whether applied in 50 or 100 gallons of water. Sprays prepared with three different solvents—soluble pine oil, xylene, and *Velsicol AR-60*—were almost equally effective and a dust was only slightly less effective. The season of larval activity began about a month after the last treatments were applied, and clusters of live larvae were collected in the treated plots.

Airplane applications of DDT were less effective than ground applications against the longe star tick, the only species present in numbers. Reductions in tick abundance developed more slowly than in the case of the ground applications, but after 6 weeks control was about 85 per cent complete in most of the plots.

Spray applications of about 1 pound of DDT per acre gave excellent control of the black-legged tick, *Ixodes scapularis* Say, in roadside plots for periods as long as 102 days.—1-10-47.

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Larvicidal Treatment of Large Areas by Ground Dispersal of DDT Aerosols[1]

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Although the insecticidal aerosol generator developed at Columbia University was designed primarily for the immediate control of adult insects (1946), advantage was taken of an opportunity to test the effectiveness of such generators for the control of mosquito larvae. The experimental area was given four treatments with the aerosol generator between December 29, 1944 and February 1, 1945. Following these treatments, comparable data were obtained over the same territory for two standard hand and power spray treatments made by the Army's 716th Sanitary Company. The results, compared for control and operational efficiency, show the aerosol method of treatment to be superior under the conditions of the experimental area.

EXPERIMENTAL AREA USED FOR TREATMENT.—The site covers about 1500 acres situated on the coastal plain between the Little Tenaru River and Dodo Creek, Guadalcanal, Solomon Islands. It consists mainly of tall thick kangaroo grass with some patches of date palms and coconut trees. There are also two cane swamps, each about 9000 sq. ft., located in the experimental area. Approximately half of the area is located outside the zone which was normally mosquito controlled. Arrangements were made with the Tenaru Malaria Control Unit to cease their larvicidal program in the controlled half for the duration of the project.

The breeding holes consisted of various ditches, ruts, marginal portions of the cane swamps, borrow pits, bomb craters, fox holes, marshy areas and puddles. In all, 52 breeding stations, increasing eventually to 88 as exploration revealed new water surfaces, were located and established in the whole area. These stations ranged in size from 3 to 2500 sq. ft.

EQUIPMENT AND MATERIALS.—An aerosol generator based upon the same principle as the previously described generator (1946), but with a capacity of 80 gallons of emulsion per hour, was used. The composition of the emulsion used in these tests follows:

25 gals., SAE No. 50 oil
15 gals., diesel oil
8 gals., xylene (20% of the oil by volume)
1 gal. emulsifier,[2] (2.5% of the oil by volume)
30 lbs. of DDT (10% of the weight of oil)
27 gallons of water (66% of the oil by volume)

The generator was operated at temperature and pressure adjusted to produce oil-DDT particles having a mass average of 16 to 20 microns diameter, suitable for larval control with the encountered wind speeds of under 3 miles per hour.

The 716th Sanitary Company used 33 standard hand sprayers (Decontamination sprayers with bordeaux whirl discs) in the general experimental area and a power sprayer operated from a weapons carrier to treat roadside ditches and holes. The power sprayer consisted of an oval tank with a capacity of 45 gallons of DDT-oil mixture plus an additional approximate 10 gallons for air. The air pressure was increased to 110 lbs. per square inch by a compressor unit also carried on the weapons carrier. This pressure gradually dropped during operation and when it decreased to 75 lbs., the air was again compressed to 110 lbs. An ordinary single hole garden sprayer was attached to the tank.

For actual field operation the following vehicles were used during the aerosol treatment:

1 Weapons carrier, 0.75 ton, for the generator and four 55-gal. drums of emulsion
1 Jeep for the supervisor of operation
1 Trailer tank, capacity 250 gallons;

and for the standard spray treatment:

2, 2.5 ton, Troop Carriers
1 Weapons carrier, 0.75 ton.

RESULTS.—The various breeding holes were dipped systematically for larvae before and after each treatment of the experimental area. The malaria vector was *Anopheles farauti*. The culicines were predominately *Culex annulirostris*. *Uranotaenia* sp. was present with *Culex* in the cane swamps and inside the jungle mar-

[1] This paper is based on work done for the Office of Scientific Research and Development under O.S.R.D. Contract OEMsr 1388 with Columbia University, Prof. Victor K. LaMer, Contract Director, and a project of the 3rd Advance Party of the Naval Medical Research Unit 2.

[2] *Tween 85.*

Table 1.—Number of *Anopheles farauti* and culicine larvae before and after each treatment. Efficiency of treatments.

Type of Treatment	Before		24–60 Hours After		% Reduction	
	A	C	A	C	A	C
1st Treatment Aerosol	11,500 (1–4)	260,000 (1–4)	0	21 (1) 40 (1–4) 100 (4)	100	99.9
2nd Treatment Aerosol	0	100,000 (1–4)	314 (1)	3,691 (1) 227 (1–4) 50 (4)	—	99.7
3rd Treatment Aerosol	2,999 (1–4)	11,228 (1–4)	174 (1–4)	3,140 (1) 165 (2–4)	94	99
4th Treatment Aerosol	1,917 (1–4)	28,744 (1–4)	0	2,546 (1–2) 183 (2–4)	100	99
5th Treatment Spray	1,416 (1–4)	30,300 (1–4)	25 (2) 140 (3)	777 (1–2) 28,600 (1–4)	90	10
			36 Hours to 4 Days After			
6th Treatment Spray	305 (1–4)	15,000 (1–4)	3,090 (1–3)	425 (1–2) 250 (1–3) 7,230 (1–4)	0	52

gin. The number of dips was standardized as a function of the water surface present in each water hole.

Table 1 was derived from the data for each breeding stations to summarize the results and to serve as a measure of the efficiency of the treatments. The number of larvae given in table 1 was obtained by the summation of the product of the average number of larvae per dip by the area in square feet of each breeding station. This procedure involves the following assumptions:

1. A dip includes one square foot of water surface. This is a rough estimate based upon the dipping technique standardized by our inspectors. An error in this estimate does not affect the per cent reduction.

2. Extent of breeding is uniform throughout the breeding station. This is a valid assumption where open pools, puddles, ruts, or ditches are involved. In the cane swamps and stations whose edges are covered with vegetation, breeding tends to be restricted to the water near these edges. For such cases, only the portions of the total area actually dipped were used in the calculations.

In Table 1, A and C represent *Anopheles farauti* and culicine larvae respectively. The numbers in parenthesis give the instar status. In calculating the percentage reduction, the number of larvae denoted as first instar were not included after 36 hours following the treatment and those denoted as (1-2) instars were not included after 60 hours. The same applies to table 2 discussed in the next paragraph.

The figures in table 1 do not inlcude two stations denoted as stations 4 and 5, since these breeding holes did not respond to the standard 5 per cent DDT-diesel oil spray treatment nor to the aerosol generator blanket treatment. Hence, the figures for these two stations are given separately in table 2 and discussed further in the next section.

Discussion.—The results clearly show that satisfactory larval control over large areas is obtainable without seeking out each breeding hole through the use of the aerosol generator. This is of particular interest as meteorological conditions in general did not favor operations. Winds after dusk were invariably less than 1 mile per hour and quite highly variable in direction. Also inversion conditions were generally not good. The third treatment was carried out under the especially poor conditions of highly variable winds associated with rain. The results of this third treatment (Table 1) were nevertheless also satisfactory.

The reduction of the *Anopheles* larvae was 100 per cent for the first and fourth aerosol treatments and 94 per cent for the third. There were no *Anopheles* larvae found after the first and prior to the second treatment. The reduction of the culicine larvae was 99 per cent or better for each of the four aerosol treatments (Table 1). The comparison of the results obtained with the aerosol generator (Treatments 1 to 4, Table 1) and with the standard sprayers (Treatments 5 and 6, Table 1) clearly shows better control of both types of larvae by the aerosol method.

Good agreement was obtained between the larval counts made by the regular Army inspectors in the controlled half of the experimental area and those made by our inspectors.

Stations Nos. 4 and 5 did not originally respond satisfactorily to blanket area treatment in spite of the fact that the aerosol did reach this location (Table 2). The standard spray treatment and the pouring of oil on these ditches also did not appreciably affect the counts of larvae at these particular stations. These stations were ditches, closely located to each other, into which flowed the waste waters of a shower hut and a laundry shed. The ditch water was viscous, had a crusted black surface and contained considerable amounts of what appeared to be solid soap. These ditches were finally brought under control by specific treatment (Table 2) with the aerosol generator from a relatively close position (20 to 200 feet up wind). An unusually heavy and uniform application of DDT was thus required to control these particular breeding stations. The heavier dosage from the hand sprayers was not sufficiently uniformly distributed to be effective.

COMPARISON OF AEROSOL AND SPRAY TREATMENTS.—Table 3 gives a summary of the important operational factors for each of the area treatments made with the aerosol generator. The number of quarts of DDT-oil per acre (about 0.5) used in the aerosol treatment compares favorably with the 2 quarts per acre put out by spray planes. The total operation hours given in column 7 covers the time interval between the arrival of equipment and personnel at and departure from the area to be treated while the eighth column gives the number of hours during which the aerosol generator actually was operated. It is seen that about half the time was spent in operation of the aerosol generator while the remaining half was

Table 2.—Efficiency of treatments on stations 4 and 5 (all *Culex*).

TYPE OF TREATMENT	BEFORE		36 HOURS TO 4 DAYS AFTER		PER CENT REDUCTION	
	4	5	4	5	4	5
1st Treatment Aerosol	36,000 (1–4)	14,000 (1–4)	14,400 (1–4)	5,600 (1–4)	60	60
Treatment Hand Spray	14,400 (1–4)	5,600 (1–4)	7,920 (1–4)	3,080 (1–4)	45	45
2nd Treatment Aerosol	7,920 (1–4)	3,080 (1–4)	10,800 (1–4)	7,000 (1–4)	0	0
3rd Treatment Aerosol	18,000 (1–4)	14,300 (1–4)	7,200 (1–4)	4,200 (1–4)	60	70
Specific Aerosol Treatment	7,200 (1–4)	4,200 (1–4)	0	0	100	100
4th Treatment Aerosol	5,400 (1–4)	0	2,160 1–2)	280 (1–2)	100	—
5th Treatment Spray	9,000 (1–4)	0	19,000 (1–4)	560 (1–3)	0	—
6th Treatment Spray	18,000 (1–4)	0	16,600 (1–4)	0	10	—

Table 3. Operational data, aerosol and standard spray treatments.

Treatment Number and Type	Acres Covered	Gals. 10% DDT-Oil Used	Gals. Emulsion Used	Quarts per Acre; 10% DDT-Oil	Pounds DDT per Acre	Total Operation Hours	Total Generator Operation Hours	Miles of Front	Rate of Travel Av. Miles per Hours	Gals. 10% DDT-Oil per 1000 Ft. of Front	Men Used in Treatment	Acres per Man Hour
Treatment 1 Aerosol	1525	227	389	0.60	0.11	11.5	5.5	8.6	1.5	5.2	3	44
Treatment 2 Aerosol	1525	186	310	0.5	.090	10.5	3.9	6.5	1.7	5.4	3	48
Treatment 3 Aerosol	1560	176	293	0.43	.079	10.3	4	5.3	1.4	6.3	3	53
Treatment 4 Aerosol	1525	210	350	0.55	.094	8	4	6.3	1.6	6.3	3	63.5
Treatment 5 Spray by 716th S.C.	1525	Gals. 5% DDT-Oil 95	—	0.12	.022	2 3 5.5 3	—	—	—	—	9 16 14 3	10
Treatment 6 Spray by 716th S.C.	1525	220	—	.028	.051	13.5 3.2 8.25	—	—	—	—	14 9 2	6.5

spent in getting into position for operation. The ninth column gives the number of miles travelled by the aerosol generator during its actual use at the average rate given in column 10. If two aerosol generators had been available, the rate of travel could have been doubled and the operational times considerably reduced. Column 11 gives the number of gallons of 10 per cent DDT-oil mixture put out by the aerosol generator for every 1000 ft. of road travelled by the aerosol generator while in actual use. In calculating the manpower efficiency in acres per man hour the total operating time was used.

Two men alternated as driver and generator operator and one man directed the field operation.

Table 3 also contains the corresponding data, where applicable, for the fifth and sixth treatments which were standard spray treatments carried out by the 716th Sanitary Company. In their first treatment a crew of 16 men worked for three hours and a 14-man crew worked for 5 hours and 30 minutes to cover about two-thirds of the total experimental area whereas a crew of 9 men, according to figures submitted, covered the remaining third, which included one of the cane swamps, in 2 hours. Indications are that neither cane swamp was effectively covered. It would be impossible, however, to hand-treat such cane areas adequately without first extensively clearing them. In this case, clearing operations would probably have made the entire cane area, instead of only the margins, favorable to breeding.

In addition, a power sprayer operated from a weapons carrier was used by the 716th to spray roadside ditches and holes. Three men working 3 hours were required for this in the first treatment and two men were used for 8 hours and 15 minutes in the second treatment.

The comparison (Table 3) of the relative manpower requirements for aerosol generator field operation and hand spray field operation reveals a factor of six in favor of the former and requires no further comment. But the distinction in the interpretation of figures expressing the quantity of DDT-oil mixture used to cover the complete area should be emphasized.

The aerosol treatments required an average of about 0.5 quarts of 10 per cent DDT-oil per acre whereas the hand spray treatments required an average of only 0.20 quarts of 5 per cent DDT-oil. Although this comparison would seem to favor use of hand sprayers from the point of view of material required, the following factors should be considered:

1. The aerosol treatment is effective for all breeding sites in the area covered regardless of their number, size, concealment, or difficulty of terrain, whereas hand equipment will miss concealed

places, cannot effectively cover uncleared swamps or marshes, and must greatly increase time and material in normally wet areas or after heavy rainfall;

2. The undeposited portion of the aerosol (about 50 per cent within the first 2000 ft. down wind) kills the adult mosquitoes over large areas.

CONCLUSIONS.—It is evident that the aerosol generator obtains very satisfactory larval control over large areas even when operations are carried out under poor meteorological conditions. It should prove to be a very useful instrument in bringing large areas rapidly under larval, as well as adult, mosquito control without the necessity of seeking out each breeding hole.

Although during this project the area was treated with as low an output as 0.5 quart oil-10 per cent DDT per acre, producing larval control to at least 2000 ft. down wind, an output of 1 quart per acre is recommended to allow a good margin of safety.

SUMMARY.—After each of four area aerosol treatments over about 1500 acres, a reduction of 99 per cent in the number of culicine larvae and of 94 to 100 per cent in the number of *Anopheles farauti* larvae. was recorded. No breakdown of the aerosol generator occurred during the treatment period of 5 weeks and mechanical operation was consistently satisfactory. Comparison with standard hand and power spray treatments shows the aerosol method is more efficient with respect to manpower by a factor of 6.[1]

[1] ACKNOWLEDGMENT.—The entomological assistance of Lt. Comdr. George E. Bohart, H(S), U.S.N.R., is deeply appreciated and gratefully acknowledged. The competent assistance of Messrs. John Epps, Paul Eschmeyer, Karl Kramer, Russel Muhl, Gail Norris, John Stuntz, and Cecil Wyman, Corpsmen, U. S. Navy, is also gratefully acknowledged. Indebtedness to the Bureau of Medicine and Surgery and, in particular, to Admiral Thomas Rivers, Commanding Officer, Naval Medical Research Unit 2, and Captain James J. Sapero, U.S.N., Malaria and Epidemic Disease Control Officer, for sponsoring this program in the Southwest Pacific Area is expressed.

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Treatment of Native Villages with the Aerosol Generator[1]

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Two villages were treated to determine whether an oil-DDT aerosol generated outside native huts can kill adults resting inside the huts during the course of treatment and to determine the protective period against mosquito adults obtainable with a single blanket treatment extending 1000 feet above and below the limits of the village.

The villages of Boromoli and Vatapouri, Big Florida, Solomon Islands, were found to be the most promising of many villages inspected, with respect to large potential adult and larval populations. Accordingly, arrangements were made with Lt. Sibley, (MC), U.S.N.R., Tulagi Area Malariologist, and Lt. Cuncannon, Commanding Officer, Siota AATC, Little Florida, to cease standard mosquito control measures within the village of Boromoli. The control measures involved weekly larvicidal treatments with hand spray equipment and hut spraying every 2 to 3 weeks. The village of Vatapouri, located north of Boromoli, was an uncontrolled area.

The mosquito population in these villages consists largely of *Anopheles farauti*. *Anopheles lungae* were also found in the jungle behind Vatapouri.

DESCRIPTION OF VILLAGES AND TERRAIN; METEOROLOGY.—Each of the villages of Boromoli, Vatapouri, and Palamaho is composed of a series of thatched huts located along a beach on a narrow plain behind which are hills and bluffs of varying heights. The distance between the villages and the hills varies considerably. Headlands extend to within 300 feet of the beach behind parts of Vatapouri whereas relatively flat floored valleys stretch over 1000 feet behind other parts of the same

[1] This paper is based on work done for the Office of Scientific Research and Development under O.S.R.D. Contract No. OEMsr 1388 with Columbia University, Prof. V. K. LaMer, Contract Director, and a project of the 3rd Advance Party of Navy Medical Research Unit 2.

village. In Boromoli, the hills are located much farther behind the village.

In general, the huts are grouped in sections of cleared ground immediately behind which is a narrow (about 100 feet) cocoanut palm grove which then leads to the jungle. The hut size averages about 12 by 10 by 6 feet. In general, the jungle line is adjacent to the road between sections of each village and between villages. Vatapouri is located about a mile above Boromoli and Palamaho is about a half mile above Vatapouri.

Previous experience in the United States showed that it is comparatively difficult to treat broken terrain because of the tendency of the aerosol to flow along the side and top of a dense growth after traversing a comparatively open region. Daytime operations are also to be discouraged because of the tendency of the aerosol cloud to rise unless there is a steady wind velocity of 5 or more miles per hour.

However, only one road running along the beach was available and operations were therefore conducted over broken terrain. Also, water transportation was available only during the day. Hence, operations were conducted during the morning. Fortunately, high wind velocities were largely prevalent.

BOROMOLI AND VATAPOURI VILLAGE TESTS.—Adult mosquito counts were made in the huts and larval counts were made in several breeding sites located behind each village. Huts in Vatapouri were used as adult check stations during the Boromoli test and huts in Palamaho were used as check stations during the Vatapouri test. Differences in morning and afternoon counts were not significant.

The breeding sites behind Boromoli consisted of 14 pools and shallow ponds, some of which were filled with cocoanut shells and much debris, or located under large logs, and in two mangrove swamps. In area, the pools and ponds varied from 20 to 450 sq. ft. and the swamps from 550 to 800 sq. ft. The distances of these sites from the road over which the treatment was made ranged from 160 to 650 feet.

Time did not permit a complete survey to be made of the breeding sites behind Vatapouri. Hence, the Vatapouri larval data in table 2 refer to only two sites, one a shallow muddy hole of 90 square feet at downwind distance of 235 feet, and the second cut-up taro field, 270 sq. ft., at least 1000 feet downwind. The culicine breeding data recorded in table 2 was also found in this taro field as well as in two tree stump holes located in the field.

The operational data is summarized in table 1.

Table 1.—Operational data. Boromoli test made March 24, 1945; Vatapouri, March 29, 1945.

	BAROMOLI	VATAPOURI
Front	0.89	1.0
Output	15	12
Sea Breeze	2.3–5.6	9
Time	51	45
Acres per Man Hour	44	55
Stability	Poor	Good
Size	10	10

Front, the distance covered by the generator carrier, is given in miles; output in gallons of emulsion per 1000 feet of front; the wind speed in miles per hour; time, the duration of the treatment in minutes; stability expresses the tendency of the aerosol to remain near the ground; size gives the aerosol average mass particle diameter in microns. In the Boromoli operation, it was possible to travel only 250 feet south of the village.

Adult and larval *Anopheles farauti* results are given in table 2. The numbers of larvae were calculated as previously explained (1946).

DISCUSSION.—The results show a satisfactory protective period in Boromoli of a minimum of 5 days for a single blanket treatment, particularly since the adult population in the check village of Vatapouri continuously increased and reached a comparatively enormous value on the fifth day after the Boromoli treatment. These results should also be compared with the rate of return of adults to huts in which the resting adults were killed with an aerosol bomb. Before treatment the huts showed 29 mosquitos: the day after each treatment 14 adults were again found in the sprayed huts and 2 days after, 29 adults were found. This is, of course, to be expected since this spraying of the mosquito adults in huts does not materially affect the total adult population of the area.

The protective period for Vatapouri, on the other hand, was much shorter.

Although the initial kill was satisfactory, a large population was present in the huts on the second day after the treatment (Table 2). This shorter protective period is due to the following factors:

a. Resting adults and breeding extended beyond the limit of toxicity to be expected from a single blanket treatment with the DDT output used. A more extensive search on the third day after treatment located nine resting adults, *Anopheles lungae*, in a tree 500 feet south of Vatapouri and 1100 feet from the road over which the treatment was made. Numerous *Anopheles* larvae, species not determined, were also found in fox-holes in this area. In Boromoli, on the other hand, breeding was limited to 700 feet from the road. Hence, a faster rate of infiltration into Vatapouri was to be expected.

b. The higher wind velocity caused a greater loss of aerosol, in treating the sections with broken terrain, when it reached the denser vegetation.

To obtain longer protective periods in such areas as Vatapouri, where breeding extends beyond 1000 feet and where the terrain is broken, 48 instead of 12 gallons of the emulsion per 1000 feet of front is recommended. Also, the generator run should extend at least 2000 feet, instead of 1000 feet, beyond the edges of the village.

For sites similar to Boromoli, where breeding is limited to distances of less than 1000 feet behind the village but where broken terrain is encountered, an output of 24, instead of 15, gallons of the emulsion per 1000 feet of front extending at least 2000 feet beyond the village edges should increase considerably the protective period.

For two weeks prior to treatment, adult culicines were abundant in the jungle behind Boromoli. The predominant species were *Armigeres malayi breinli* and *Aëdes quasiscutellaris*. Half a dozen were usually attempting to bite the ankles at all times in dense shade. Seven hours after the treatment, a 20-minute count in a spot particularly favorable for mosquitoes yielded only one *Armigeres* and no *Aëdes*. The adult population continued low in all the area behind Boromoli where *Anopheles* breeding stations were being checked. Seven days later, 2 to 3 mosquitoes were usually attempting to bite.

Satisfactory *Anopheles* larval control was obtained as a result of the Boromoli treatment in spite of the broken terrain. The percentage of fourth instars did not become appreciable until the eighth day after the treatment. A large swamp, about 1000 feet square, located some 2000 feet from the Boromoli road appeared to be an ideal location for *A. farauti* breeding but an extensive search revealed no such breeding.

In the Vatapouri treatment, larval con-

Table 2.—Population of larvae of *Anopheles farauti* and culicine mosquitoes and of the adults *A. farauti* mosquitoes in huts before and after treatment. Numbers in parenthesis give the larval instars

		Days After							
Anopheles Adults	Before	8 (hours)	6 (hours)	1	2	3	5	6	8
Boromoli	34		0	0	2	4	4	15	22
Checks	5		5	9	12	27	27		
Vatapouri	276	6		7	89	33			
Checks[1]	24	19		7	12	8			
Anopheles Larvae									
Boromoli	6400 (1–4)		14 (1)	28 (1)	1800 (1)	4500 (1)		6200 (1–2)	4400 (1–4)
Vatapouri	234 (1–3)	0		9 (1–5)	34 (2)	54 (1–3)			
Culicine Larvae									
Vatapouri	355 (1–4)	0		0	90 (1–4)				

[1] It is possible that the decrease that occurred 1 day after the treatment resulted from the treatment since Palamaho is about 150 feet above the edge of the treatment.

trol was obtained in some sections but was not complete enough throughout the treated area to be completely satisfactory. Thus in the far edge of the cut up taro field, four newly hatched first instars, two second, one third and one fourth instars as well as one pupa were found about 30 hours after the treatment (Table 2). Also, on the third day after treatment, an extensive field of fox-holes was located at the base of a bluff, 500 to 1000 feet south of the village of Vatapouri and 850 to 1275 feet down wind, in which considerable larvae were found. The use of the larger output previously recommended should give the more extensive control necessary.

As in previous experience, the distance of culicine larval control was more limited than that of *Anopheles* larval control. The day following the Boromoli treatment, tree-holes, cocoanut shells and tin cans were checked for culicine larvae and control of such breeding places was not obtained beyond 250 feet from the road. And in the Vatapouri treatment, erratic culicine control resulted largely from the high wind velocity and varying nature of the terrain. Thus a barrel located near the beach had abundant breeding before and after this treatment. With a 9-mile per hour wind, the amount of 10 micron diameter aerosol that will deposit even at the very short distance of 75 feet is negligible. The measure of control obtained farther back in the denser vegetation (Table 2) resulted from the relatively slower wind velocity therein.

CONCLUSIONS AND SUMMARY.—A single treatment of two native villages with 10-micron mass particle diameter aerosol with a dosage of about 5 pounds DDT per 1000 feet of front is effective against *Anopheles farauti* mosquitoes in and outside of thatched huts and produced a protective period of at least 5 days in one village and 1 day in the second. This difference was largely due to the more extensive breeding in the area of the second village.

To obtain an appreciable protective period in a native village composed of a series of huts located more or less in the open but bordered by a jungle in which breeding holes extend beyond 1000 feet, an output of about 20 pounds of DDT per 1000 feet of front, the front being extended 2000 feet beyond the edges of the village, should suffice. If the breeding sites are within 1000 feet of the village, 10 pounds of DDT per 1000 feet of front will suffice.[1]

[1] ACKNOWLEDGMENT.—The entomological assistance of Lt. Comdr. George E. Bohart, H(S), U.S.N.R., is deeply appreciated and gratefully acknowledged. The competent assistance of Messrs. John Epps, Paul Eschmeyer, Karl Kramer, Russel Muhl, Gail Norris, Jack Stuntz, and Cecil Wyman, Corpsmen, U. S. Navy, is gratefully acknowledged. Indebtedness to the Bureau of Medicine and Surgery and, in particular, to Admiral Thomas Rivers, Commanding Officer, Navy Medical Research Unit 2, and Captain James J. Sapero, U.S.N., Malaria and Epidemic Disease Control Officer, is expressed for sponsoring this program in the Southwest Pacific Area.

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Aerosol Generator as Used for Sand Fly Control[1]

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While the larvicidal project reported in a previous paper was in progress, a species of beach breeding sand fly, *Styloconops albiventris* de Meijere, became a nuisance to Fleet Hospital 108 Rest Camp, Guadalcanal, Solomon Islands. This fly has been reported from New Guinea and New Britain as well as from several of the Solomon Islands. Permission was readily obtained from Commander Stevens (MC) in charge of the Rest Camp, to use the Aerosol Generator to determine the control efficiency of 10 per cent DDT-oil aerosol. The project was conducted concurrently with the larvicidal tests.

Very little entomological information regarding these sand flies is available. It was determined by the abundant emergence of adults in traps that the larvae breed in the moist sand of the high tide zone. Time did not permit the isolation of the larvae from their sand environment.

[1] This paper is based on work done for the Office of Scientific Research and Development under O.S.R.D. Contract No. OEMsr 1388 with Columbia University, Prof. Victor K. LaMer, Contract Director, and a project of the 3rd Advance Party of the Navy Medical Research Unit 2.

Hence, neither the developmental cycle nor the depth at which they breed has been determined. An experiment performed to determine the effect of deposited aerosol on larvae strongly suggests that breeding is confined to one or two sand layers beneath the surface. The quantity of water required for breeding is not known though the site used for the larval experiment was washed over by the sea water and remained under water during certain high tides.

Where the flies rest was not determined. Although it was not our purpose to conduct extensive entomological work, vegetation and beach debris were examined for flies around a spot where breeding was heavy and biting rates were high. No sand flies were so located at a time of the day when the species is inactive. It was also determined that they are not attracted to lights and do not enter dwellings at night.

Biting counts made at different times of the day show a fairly well reproducible biting peak at 0830 (Table 1). Between 1000 and 0730 biting counts are in the neighborhood of zero. Counts made in the shade and in sunlight show that, on the whole, this particular sand fly exhibits no preference while on the wing. Activity, also, does not appear to increase on cloudy days. Activity does however appear to be discouraged by winds above 5 miles per hour. Migratory habits of these sand flies have not been studied. Though it is believed that their flight range is short and that they remain within the area of the beach, several sand flies were found on different occasion hundreds of feet inshore and in one case a sand fly was found on a float a couple hundred feet offshore.

Table 1.—Variation in biting count with time. These are 5-minute counts with only arms exposed.

DATE WIND, MI./HR. TIME	February 7 Less than 3 SUN	February 10 Less than 1 SUN
0725	21	
0735	45	
0750	45	
0800		25
0805	52	
0815		46
0820	75	
0830		53
0835	50	
0845		39
0850	45	
0900		34
0905	40	
0915		38
0930		24

The lethal dosage or the DDT dosage relative to that required for adult mosquitoes is also unknown to us for any species of sand fly.

Sand fly biting counts were made over the time corresponding to the peak of biting activity. The counts show the number of flies obtained in 5 minutes on the exposed arms and legs. The flies were killed when counted. Counting stations were located at 400-foot intervals along the beach and are denoted as Beach Stations in the tables. Counting stations were also located at several points as far as 750 feet inshore but data so obtained is of no significance because of the very small number, if any, of sand flies found at these locations. Starting and end stations in the tables refer to the biting counts made at the points at which the generator run started and ended. Check stations were located on both sides of the beach covered by the aeroso'.

Three different type aerosol treatments were made to determine the most efficient type of operation for adult and larval control.

DESCRIPTION OF THE BEACH.—In the area treated the bare beach is generally a narrow zone, 15 to 20 ft. wide at low tide. Immediately inshore from the beach is a zone of loose dry sand supporting a low growth of a sweet potato-like plant. Crab holes are numerous in this zone and may constitute small breeding areas. Inshore from this are the encampments among scattered palms. The beach generally was strewn with debris such as shells, sticks, cocoanuts, etc.

EQUIPMENT AND MATERIAL.—The aerosol generator and emulsion composition used in the larvicide project, reported in the previous paper, were used in this project. Operations can be carried out by a driver and generator operator. Over an unfamiliar run a supervisor is necessary.

TYPES OF TREATMENT.—The first treatment was made on January 6, 1945. Not having any previous knowledge of method of treatment, it was decided to make a blanket treatment with 16 micron diameter aerosol for adult kill at the first

sign of biting in the morning. This treatment was made from 0610 to 0625 over a road approximately parallel to the beach line, 25 feet from the beach at the narrowest point and about 700 feet at the widest. It was soon discovered that this treatment was made too early. Consequently, it was repeated again at 0800. After the first aerosol blanket treatment, the beach line was sprayed with particles about 300 microns in diameter for control of larvae. (The generator was operated at a much lower temperature than usual.)

During this operation, a land breeze 1 to 1.5 miles per hour prevailed. Length of beach treated was 1 mile. For other operational data see table 2.

Table 2.—Operational data. Size refers to the average mass particle diameter in microns.

Treatment	Size	Emulsion Gals. Used	Oil—10% DDT Gals. Used	Gallons Oil—10% DDT per 1000 Ft. of Beach
First				
Road	16	62	37	7.4
Beach	300	50	24	4.8
Second				
Road	10	80	48	5.3
Beach	300	35	21	5.0
Third				
Beach	16	80	48	7.1

The second treatment was applied February 1, 1945. To determine the efficiency of the spray treatment, the beach length to be treated was extended from 1 to 1.7 miles and about half was treated with spray (300 micron diameter particles) and aerosol (10 micron diameter particles) while the second half was given only an aerosol (10 micron diameter particles) blanket treatment. The spray treatment was made along the beach and the aerosol treatment from the inshore road. The aerosol treatment was run from 0745 to 0845 with a land breeze, 2 to 3.5 miles per hour. For other operational data see table 2.

The third treatment was applied February 8, 1945. In the belief that sand flies rest in the moist sand and within short distances of the high water mark, the beach was treated from the seaward side to give maximum aerosol dosage and deposition in this region. A 16-micron diameter aerosol treatment was made at a time, 0945 to 1040, when the sand flies are largely resting. The sea breeze ranged from 3.5 to 5 m.p.h., and the weapons carrier was driven with 2 wheels in the water at low tide. The length of beach treated was 1.4 miles. For other operational data see table 2.

Table 3.—Reduction after first treatment, January 6, 1945. Wind, in this and Tables 4 and 5, refers to average wind speed in miles per hour prevalent during the counting period.

Station Locations	Biting Count Before Treatment	Per Cent Reduction Days After Treatment				
		1	4	5	10	20
Wind	1	2	2	0.5	3	4
Beach	324	95	90	96	90	90
Start and End	45	10	10	−30[1]	55	−15[2]
Check	100	−2	15[3]	40[3]	65	70

[1] The increase in the number of sand flies occurred only at the point corresponding to the end of the run.
[2] A large increase occurred at the point corresponding to the start of the run while at the end point the count went down practically to zero.
[3] The reduction occurred in the east end check stations while the west end check stations showed an increase.

Table 4.—Reduction after second treatment, February 1, 1945.

Station Locations	Biting Count Before Treatment	Per Cent Reduction Days After Treatment	
		1	2
Wind	4	2	3
Beach	125	75	98
Start and End	38	95	100
Check	51	20	20[1]

[1] Count at check stations on east end went down considerably while that at the west end remained practically constant.

Table 5.—Reduction after third treatment, February 8, 1945.

Station Locations	Biting Count Before Treatment	Per Cent Reduction Days After Treatment		
		2	4	9
Wind	1	0.5	1	1
Beach	294	93	88	86
Start and End	12	−100	−85	88
Check	89	− 30	−15	63[1]

[1] Check count at west end decreased to zero while check count at east end was over double the initial count.

RESULTS AND DISCUSSION.—The results summarized in tables 3, 4, and 5, and compared in table 6, show that the three types of treatment are of about equal

efficiency. The only noticeable difference is the comparatively slower action of the 10-micron diameter aerosol used alone in the second half of the second treatment. Any other difference is clouded by the variation that occurred in the count at check stations (Tables 3, 4, and 5). The protective period afforded by each of the treatments is at least 4 days but the periodicity of treatment is affected by the rate of breeding as well as by the migratory rate. Though the beach conditions appear to be constant, the rate of breeding does not appear to be so. Thus for weeks after the first treatment, no treatment war required but a third treatment was needed 6 days after the second. At the time the party left Guadalcanal, 15 days after the third treatment, the beach still required no treatment. Yet, during this time, adult emergence obtained in our larvae experiment (next section) was high.

During the third treatment the effect of the aerosol on various species of flies was noted. Sand flies were observed dead and stuck to the "sweetpotato" leaves a few minutes after the treatment. Various small beach flies of the families Chloropidae and Ephydridae as well as Myrmicine ants were observed struggling on the beach and in sand hollows under the vegetation. Flies of the genus *Musca* and two species of blowflies, *Chrysomyia nigripes* and *C. megacephala* were likewise affected. Innumerable springtails appeared to be unharmed shortly after the treatment. These observations were made within a distance of 100 feet downwind from the generator front.

EFFICIENCY OF AEROSOL DEPOSIT ON LARVAL CONTROL.—To determine the efficiency of the deposited aerosol, a metal trap about 2 by 5 by 2 ft. was set over the ground in the vicinity of a check station at which biting counts were consistently high. The spot chosen is washed over by the sea water and remains under water during certain high tides. The ground was then treated with a 16 micron diameter aerosol in a manner similar to that used in the third treatment. A second trap of wood, 3×5×0.5 ft., was then set over the ground alongside the first trap. The chosen spot proved to be very favorable for breeding and results obtained are very striking (Table 7). Interchanging the traps had no effect on the results. The results clearly show that the particles deposited from a 16-micron diameter aerosol, with a wind speed of about 5 miles per hour, are very efficient in controlling sand fly larvae. Of course, in actual use, the long protective period obtained in this experiment under tight boxes is not to be expected.

Very curiously, during this period of emergence the biting rate at the location of this experiment was practically zero. No explanation based on present evidence can be offered for this phenomenon.

Table 6.—Comparison of efficiency of treatments for the three treatments.

TREATMENT	BITING COUNT BEFORE TREATMENT	PER CENT REDUCTION DAYS AFTER TREATMENT			
		1	2	4	5
1	324	95		90	96
2	125	75	98		
3	294		93	88	

Table 7.—Effect of deposited aerosol upon Sand Fly larvae. Mass particle diameter, 16 microns. Aerosol output at a rate of 7.1 gallons of oil-10% DDT per 1000 feet of front. Wind speed, 3–5 m.p.h.

DAY	NUMBER OF SAND FLIES EMERGED		
	Ground Treated		*Ground Untreated*
2/12			
2/13	0		0
2/14	1		29
2/15	1		54
2/17	9		37
2/19	0		79
2/21	0		22
2/22	0	(Traps Interchanged)	26
2/23	0		11

CONCLUSIONS AND SUMMARY.—The aerosol generator will obtain efficient sand fly control. It is probable that the aerosol generator will prove to be efficient in the control of other species of flies.

When used for the control of beach breeding sand flies, it is recommended that the beach be treated from the seaward side at low tide with a dosage of about 7 to 7.5 gallons of oil-10 per cent DDT per 1000 feet of front projected as a 16 micron particle diameter aerosol. If the wind speed is however greater than 5 miles per hour, a larger particle sized aerosol should be used (1946) for larval control. The treatment should extend at both ends at least 500 feet beyond the beach line to be controlled.[1]

[1] See note 1, page 316.

Salinity Tolerance of *Anopheles quadrimaculatus* and Habitat Preference of *A. crucians bradleyi*

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During 1944–45 in connection with the Maryland Project, Malaria Control in War Areas, an investigation was made of the occurrence of *Anopheles quadrimaculatus* Say in the vicinity of Scotland, St. Marys County, where a population of from 2,000 to 10,000 mosquitoes per barn was commonplace. The principal source of these mosquitoes was found to be Deep Creek, a large brackish lagoon. This paper describes the distribution of *A. quadrimaculatus* in Deep Creek with respect to different salinities, aquatic vegetation, and associated mosquito species.

The principal purpose of this paper is to establish, for one locality, a carefully defined example of appreciable salinity tolerance of *Anopheles quadrimaculatus* which is generally regarded as a distinctly freshwater anopheline (Boyd 1930; Bradley & King, 1941; and King, *et al.* 1944). To the writer's knowledge, there is no comprehensive report on the occurrence of this mosquito in brackish waters in the literature extant. Notes on the selective occurrence of *A. crucians bradleyi* King and *Culex salinarius* Coq. are also included.

METHOD.—Sampling stations were selected for Deep Creek in such a manner that the range of salinities of the lagoon from minimum to maximum would be covered adequately. Otherwise these stations were apparently uniform with respect to favorability for occurrence of *Anopheles quadrimaculatus*.

Pint capacity white enamel dippers were used in sampling for breeding. After collection all fourth stage larvae were placed in 95 per cent alcohol and later microscopically examined (27x through 90x) for identification. Keys in King *et al.* (1944) and in Ross & Roberts (1943) were used for making determinations. Dr. Alan Stone[3] has kindly verified identifications of representative series of anopheline larvae from the various salinities reported here. Pupae were collected and held for emergence. Often additional substantiation of larval identifications was thereby made.

Water for pH and salinity determinations was collected in 1-quart glass-stoppered bottles at each sampling station at the same time larval inspection was made. These samples were tested within 72 hours after collection.

The chemical determinations were made by chemists of the Maryland State Department of Health. All pH determinations were made colorimetrically using Hellige comparator discs. Salinity was determined by the Volhard method and is expressed in parts per million soluble chlorides. Standard sea water is considered to contain 31,000 p.p.m. soluble chlorides.

Four barns, usually housing animals at night, evenly distributed in close proximity to Deep Creek, were checked periodically to determine trends of the adult mosquito populations for comparison with findings on breeding.

CHARACTERISTICS OF DEEP CREEK.—Deep Creek has been separated from the Chesapeake Bay by a barrier beach. Through the ages sand and debris, washed over the barrier beach by storms, have effectively separated the north and south arms of Deep Creek by a marshy deposit of considerable area. Through this marsh a narrow and in many places very shallow channel from the north arm connects with a common channel of greater depth and width leading from the south arm to the barrier beach.

There are no flowing streams emptying into Deep Creek. The total watershed draining into this lagoon does not exceed 1.5 square miles.

Deep Creek is a uniformly shallow body of water. It was less than 3 feet deep over most of its area during the summer of 1944

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Table 1.—Monthly precipitation as recorded by the U. S. Weather Bureau at Solomons, Maryland (16 miles north of Deep Creek).

	—1944— (53RD YEAR OF RECORD)		—1945— (54TH YEAR OF RECORD)	
	Precipitation (Inches)	Departure (Inches)	Precipitation (Inches)	Departure (Inches)
January	3.30	+0.24	2.84	−0.22
February	3.53	+0.58	2.51	−0.44
March	6.67	+3.41	0.74	−2.52
April	4.80	+1.63	3.17	0.00
May	0.47	−2.62	3.76	+0.67
June	2.71	−0.63	5.07	+1.73
July	2.98	−1.42	17.44	+13.04
August	1.87	−2.29	1.02	−3.14
September	2.96	+0.01	4.57	+1.62
October	2.83	+0.24	2.37	−0.22
November	3.38	+1.23	4.08	+1.93
December	2.19	−0.47	6.26	+3.60
(Totals)	37.69	−0.09	53.83	+16.05

with its greater depths ranging from about 4 to 6 feet.

Aquatic plant life was of the horizontal type, consisting of sago pondweed, *Potamogeton pectinatus* L., with accompanying green algae. At the peak of the 1944 season, these plants formed a luxurious matted coverage extending over areas of 100 acres (95 per cent) of the north arm and 15 acres (20 per cent) of the south arm. Apparently as a result of high water levels and other associated changes, the 1945 coverage amounted to only about one-fourth of that of 1944.

The marsh separating the north and south arms was characterized by a great variety of salt grasses and sedges, with saltmarsh cord-grass, *Spartina alterniflora*, and various rushes, Scirpus spp. predominating.

Salinity data on the various sampling stations are to be found in tables 2, 3, and 4. The consistently higher concentrations of the south arm are believed to be due to less watershed and greater accessibility to storm tides flooding in from the Chesapeake Bay through the outlet channel.

The higher salinities of 1944 as compared with those of the first half of 1945 are accountable on the basis of contrasting weather conditions. Through much of the 1944 season, rather dry weather prevailed (Table 1), and the water level gradually decreased to a minimum on September 1 when Deep Creek appeared to be about 5 inches below the high water level observed on July 1. The accompanying increases in salinity during this period indicate that losses of water by evaporation may have been the principal influence affecting increased concentration; however, on a number of occasions northeast storm tides flooded over the barrier beach which undoubtedly contributed to increasing salinity, especially in the more accessible south arm.

During the first half of the summer of 1945 a very wet season prevailed with rainfall above average during the latter part of May, the month of June, and especially in July when over 17 inches fell (Table 3). As a result of the excessive precipitation, the water in Deep Creek continued to rise from a rather high level attained during the spring until July 16, when the barrier beach was topped at a level exceeding by almost 2 feet the minimum observed in 1944. The flood of overflowing water augmented by 2 additional days of very heavy rainfall, cut a broad deep channel through the barrier beach. This outlet persisted after the floodwaters subsided, leaving Deep Creek open to tidal action of the Chesapeake Bay during a period extending from about July 20 through November 7 when this study was concluded.

The salinity of the north and south arms consistently decreased with the increasing water levels and heavy rainfall of July, until the influence of the tidal action began shortly after the breaching of the barrier beach. Following this last development a period of very rapid increases in salinity occurred, being more pronounced in the more accessible south arm.

DISTRIBUTION OF *Anopheles quadrimaculatus* IN RELATION TO SALINITY.—In tables 2, 3, and 4 are shown the results of larval dippings together with pH and salinity determinations for each collecting station is a graphical representation of the salinity trends of the north and south arms together with the observed occurrence of *A. quadrimaculatus*.

As shown in table 2 the north arm of Deep Creek was found to produce *Anopheles quadrimaculatus* exclusively during the 1944 season while the south arm was found to be free of all mosquito larvae except for a very sparse occurrence of *A. crucians bradleyi*. The conclusion as to the

Table 2.—Results of chemical determinations and entomological inspection of Deep Creek and adjacent lagoon during the 1944 season.

Station Number	Date of Sampling	Chemical Data		Anopheles Larvae and Pupae			
		pH	Salinity p.p.m.	Number of Dips	Average Number per 10 Dips	Results of Identifications (Based upon 4th stage Larvae and pupae only)	Ave. No. *A. quadrimaculatus* per 10 Dips
				North Arm			
1	July 1	8.9	1900	20	17.0	8 *A. quadrimaculatus*	4.0
1	Sept. 1	9.6	2300	30	19.6	7 *A. quadrimaculatus*	2.3
1	Sept. 17	9.2	2100	20	33.0	16 *A. quadrimaculatus*	8.0
1	Oct. 16	8.9	2100	50	6.4	7 *A. quadrimaculatus*	1.4
2	June 22	9.3	1600	30	15.0	15 *A. quadrimaculatus*	5.0
2	July 1	—	1600	0	—	— —	—
2	Sept. 1	8.9	1900	10	210.0	17 *A. quadrimaculatus*	17.0
2	Oct. 16	8.7	1900	140	5.6	19 *A. quadrimaculatus*	1.4
3	Sept. 17	9.0	1400	20	13.5	8 *A. quadrimaculatus*	4.0
4	Sept. 17	9.3	2400	60	13.6	40 *A. quadrimaculatus*	6.7
4	Oct. 16	9.7	2800	70	0.56	1 *A. quadrimaculatus*	0.43
				South Arm			
5	July 1	7.4	4400	10	0.0	— —	0.0
5	Aug. 11	—	—	60	0.0	— —	0.0
5	Sept. 1	8.7	6100	60	0.0	— —	0.0
6	July 1	8.4	4690	0	—	— —	—
6	Sept. 1	9.4	6100	180	0.55	4 *A. crucians bradleyi*	0.0
6	Oct. 16	8.8	6300	420	0.0	— —	0.0
				Outlet Channel			
—	Sept. 1	8.1	4200	210	0.29	3 *A. crucians bradleyi*	0.0
				Adjacent Lagoon			
—	July 1	8.4	4500	30	0.66	2 *A. crucians bradleyi*	0.0

absence of *A. quadrimaculatus* from the south arm is based upon intensive inspection except on July 1 when only 10 dips were made at Station 5. Altogether 730 dips were made from July 1 through October 16, which contrasts with 450 dips and 139 identified larvae of *A. quadrimaculatus* for the north arm.

The chemical data show the pH to be similar in both arms of Deep Creek, but the salinity is markedly lower in the north arm ranging from 1400 to 2800 parts per million soluble chloride as compared with values ranging from 4400 to 6300 for the south arm. Since the plant coverage present at the sampling stations was the same for both arms of Deep Creek and since there was no other observed difference between these two portions of the lagoon, the salinity is considered to have been the factor excluding establishment of *Anopheles quadrimaculatus* in the south arm. On this basis, the maximum breeding tolerance of this mosquito exists somewhere between 2800 and 4400 p.p.m. soluble chlorides.

That continuous breeding did not exist near 4400 p.p.m. is further evidenced by the absence of *Anopheles quadrimaculatus* from a sample of 210 dips made in the outlet channel of Deep Creek on September 1, 1944 at a salinity of 4200 p.p.m. soluble chlorides as well as a sample made on July 1, 1944 in an adjacent lagoon having a salinity of 4530 p.p.m. soluble chlorides. As in the case of Deep Creek, these situations possessed Sago pondweed and algae coverage. Judging by rainfall during the month of June together with the absence of high storm tides, there is good reason to believe the salinities of both Deep Creek and the adjacent lagoon during June varied little from those determined for July 1.

Results of the 1945 season are shown in tables 3 and 4. It is significant from table 3 that during the first half of the season breeding of *Anopheles quadrimaculatus* was found in the south arm which had

Table 3.—Results of chemical determinations and entomological inspection of Deep Creek during the pre-tidal period of the 1945 season.

Station Number	Date of Sampling	Chemical Data		Number of Dips	Anopheles Larvae and Pupae		
		pH	Salinity p.p.m.		Average Number per 10 Dips	Results of Identifications (Based upon 4th stage Larvae and pupae only)	Ave. No. *A. quadrimaculotus* per 10 Dips
				North Arm			
1	Apr. 27	9.8	1400	200	0.025	1 *A. quadrimaculatus* 3 *A. c. bradleyi*	0.05
1	May 17	—	1600	240	1.33	6 *A. quadrimaculatus* 3 *A. c. bradleyi*	0.25
2	Apr. 27	9.1	1400	155	0.531	5 *A. quadrimaculatus* 1 *A. c. bradleyi*	0.32
2	May 17	—	1500	255	1.29	17 *A. quadrimaculatus*	0.67
2	July 2	—	1400	40	6.25	6 *A. quadrimaculatus*	1.50
3	Apr. 27	—	1300	10	1.00	Small larva	0.00
4	Apr. 27	8.1	1500	20	0.05	Small larva	0.00
4	May 18	—	1600	60	2.38	4 *A. quadrimaculatus* 3 *A. c. bradleyi*	0.067
4	July 2	—	1500	90	10.7	2 *A. quadrimaculatus* 4 *A. c. bradleyi*	0.22
				South Arm			
5	Apr. 27	8.8	2800	150	1.07	16 *A. c. bradleyi*	0.00
5	May 17	—	2900	178	0.39	5 *A. quadrimaculatus*	0.28
5	July 2	—	2700	175	3.42	10 *A. quadrimaculatus*	0.57
6	Apr. 27	—	2800	400	0.38	5 *A. c. bradleyi*	0.00
6	May 17	—	2900	350	1.51	7 *A. quadrimaculatus* 4 *A. c. bradleyi*	0.20
6	July 2	—	2700	170	10.25	12 *A. quadrimaculotus* 5 *A. c. bradleyi*	0.71

been reduced in salinity to 2900 p.p.m. soluble chlorides on May 17. These observations substantiate the belief that the breeding tolerance of *A. quadrimaculatux* may be high as 2900 p.p.m. soluble chlorides. Breeding was found as usual in the north arm at salinities ranging from 1200 to 1600 p.p.m. soluble chlorides. There was no significant difference in the density of identified *A. quadrimaculatus* breeding between the two arms except on April 27 when apparently this mosquito had not yet established itself in the south arm.

After the rapid increases in salinities occurred following the introduction of tidal action, larvae and pupae of *Anopheles quadrimaculatus* were observed surviving in salinities as high as 5200 p.p.m. soluble chlorides (Table 4). Rearing of pupae collected on September 28 from Station 1 yielded an apparently normal female *Anopheles quadrimaculatus* among several *A. crucians bradleyi*. Based on an estimate that the period from egg to fourth instar larva takes approximately three weeks during the month of September, the fourth stage *A. quadrimaculatus* larvae and pupae collected at these high salinities must have started development at salinities near 3000 p.p.m. soluble chlorides. Therefore, the finding of these larvae indicates their ability to survive and develop when salinities of breeding waters are gradually increased from about 3000 to 5200 p.p.m. soluble chlorides.

It should be noted that, despite the occurrence of appreciable numbers of *Anopheles quadrimaculatus* at salinities as high as 5200 p.p.m. soluble chlorides, a definite reduction in density of this species was apparent, a fact which cannot be considered as being due altogether to seasonal decline. Comparison of table 4 (Station 1), August through September, with the corresponding period of 1944 in table 2 shows this difference which may represent both a mortality and a cessation of new breeding as a result of excessive salinity.

The complete absence of *Anopheles*

Table 4.—Results of chemical determinations and entomological inspection of Deep Creek during the tidal period of the 1945 season.

Station Number	Date of Sampling	Chemical Data		Anopheles Larvae and Pupae			
		pH	Salinity p.p.m.	Number of Dips	Average Number per 10 Dips	Results of Identifications (Base upon 4th stage Larvae and Pupae only)	Ave. No. *A. quadrimaculatus* per 10 Dips
				North Arm			
1	Aug. 24	—	1800	15	101.3	24 *A. quadrimaculatus*	16.0
1	Sept. 25	—	5200	220	8.90	4 *A. quadrimaculatus* 41 *A. c. bradleyi*	0.18
1	Sept. 28	—	5000	176	7.15	8 *A. quadrimaculatus* 35 *A. c. bradleyi*	0.46
1	Oct. 17	—	6000	400	0.32	2 *A. c. bradleyi*	0.0
1	Nov. 7	—	6100	—	—	—	—
2	Aug. 24	—	2800	—	—	—	—
2	Sept. 25	—	5100	85	4.35	10 *A. c. bradleyi*	0.0
3	Sept. 28	—	4800	40	3.25	3 *A. quadrimaculatus*	0.19
4	July 19	—	450	—	—	—	—
4	July 31	—	800	—	—	—	—
4	Aug. 28	—	3000	250	7.40	59 *A. quadrimaculatus* 4 *A. c. bradleyi*	2.36
				South Arm			
5	July 19	—	210	—	—	—	—
5	July 31	—	3900	—	—	—	—
5	Aug. 24	—	5600	150	0.0	—	0.0
5	Sept. 25	—	6000	—	—	—	—
6	July 19	—	870	—	—	—	—
6	July 31	—	3100	200	1.40	9 *A. quadrimaculatus* 3 *A. c. bradleyi*	0.45
6	Aug. 24	—	5600	650	0.184	All small larvae	0.0
6	Sept. 28	—	6100	280	0.107	All small larvae	0.0

quadrimaculatus on October 19 indicates that the maximum survival tolerance of this species was reached at or near 5200 p.p.m. soluble chlorides. Furthermore, despite intensive sampling, *A. quadrimaculatus* was not found in the south arm at salinities of 5600 and 6100 p.p.m. soluble chlorides. These results are a further indication of the inability of *A. quadrimaculatus* either to breed or to survive in such high salinities.

Mosquitoes Associated iwth Anopheles quadrimaculatus in Deep Creek—Data in tables 3 and 4 also show appreciable occurrence of *A. crucians bradleyi* throughout the 1945 season. It is interesting to note that this species was found almost exclusively either in the marsh separating the north and south arms or in grasses growing along the edges of Deep Creek. The fact that the marsh and grassy edges were high and dry during the 1944 season probably accounts for the near absence of these mosquitoes from table 2.

Anopheles crucians bradleyi was hardly ever found in pondweed except in the spring and fall when moderate numbers were observed. It seems that this vegetation at sufficiently low salinities during the summer breeds *A. quadrimaculatus* exclusively. The fact that substantial occurrence of *A. crucians bradleyi* larvae in Sago pondweed was observed only in the spring and fall indicates that the limiting factor may be one of excessively high temperatures being attained during the summer months in the shallow, supernatant film of water existing between the surface and the barely submerged matted vegetation.

Culex salinarius usually occurred with *A. crucians bradleyi* but always in less numbers. *C. salinarius* exhibited the same tendencies with respect to vegetation and season of occurrence, as *A. crucians bradleyi*, and was the only other mosquito found associated with *A. quadrimaculatus* in Deep Creek.

Adult Mosquitoes in the Vicinity of Deep Creek—As mentioned at the beginning of this paper observation of 2000 to 10,000 *Anopheles quadrimaculatus* per barn was not unusual at this locality during 1944. As a result of reduced breeding surface, adult populations were not so heavy in 1945, 2000–3000 per natural resting place being characteristic until late summer. Significantly, by September 25, 200 was the highest count found in any barn. This reduction coincides with the diminution of breeding in Deep Creek caused by the high salinities resulting from tidal action.

Adults of *Anopheles crucians* (presumably *bradleyi*) occurred in numbers proportional to larval findings with practically all counts ranging between 20 and 100 per barn. However, on one occasion (October 16, 1944), 1050 females were counted in a single barn. Adults of *Culex salinarius* were practically absent from resting places except in 1945 when moderate numbers were seen. It is noteworthy that only three females of *A. punctipennis* (Say) were ever seen among the hordes of *A. quadrimaculatus*. The *A. punctipennis* records were made on October 16, 1944 (1 female) and on April 27, 1945 (3 females). *A. atropos* D. and K. was never found.

SUMMARY.—Mosquito occurrence in Deep Creek, St. Mary's County, Maryland is described for the summers of 1944 and 1945 with respect to salinity, pH, and types of vegetation.

Deep Creek was ideally suited for studies of salinity tolerance since it presented uniform breeding conditions and at the same time a wide range of salinities which underwent little if any short period fluctuations but which conveniently underwent gradual seasonal changes.

At this locality under relatively constant salinities, the salinity tolerance for continuous substantial occurrence of *Anopheles quadrimaculatus* was established to be as high as 2900 p.p. soluble chlorides (9.4 per cent seawater). At relatively constant salinities, between 4400 and 6300 p.p.m. soluble chlorides, *A. quadrimaculatus* was never found—evidently because the critical point of its salinity tolerance was exceeded.

On one occasion, following approximately a 13-fold increase in salinity over a period of 36 days, considerable numbers of *Anopheles quadrimaculatus* were found at concentrations as high as 5200 p.p.m. soluble chlorides (16 per cent seawater). In this case, it is indicated that the specimens found were survivors whose development began at lower salinities.

Anopheles crucians bradleyi and *Culex salinarius* were the only other mosquitoes observed to occur in Deep Creek. Both of these species seemed to be distributed with little regard to salinity, but were found in situations where grasses and rushes provided emergent vegetation of appreciable height. An exception was noted in the spring and fall when larvae were found in the exposed water surface associated with the Sago pondweed-algae coverage.

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Effect of Clothing Color on the Rate of Attack of *Aëdes* Mosquitoes[1]

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The color preferences of several genera and species of mosquitoes have been studied by different investigators. Ko (1925) collected the mosquitoes resting on pieces of colored cloth which had been fixed to the ceiling at regular intervals. He concluded that *Anopheles* preferred yellow, white, deep red, and green, to blue, purple, red, and black, and that the preference was reversed in *Culex* and *Aëdes*. Brighenti (1930) tested the effects of different colored washes on the ceilings of cattle sheds on *Anopheles maculipennis* Meig. He found that the order of preference was carmine red, violet, chrome yellow, white, green, and cobalt blue.

Brett (1938) investigated the color preferences of *Aëdes aegypti* (L.) females that were confined in cages. When the test colors were compared with black, the order of preference was black, red, heliotrope, brown, gray, white, blue, khaki, green, light khaki, and yellow; when compared with white, the preference was red, black, brown khaki, green, blue, heliotrope, yellow, white, and light khaki.

The purpose of the present investigation was to determine what effect different colored clothing would have on the biting rate of several species of *Aëdes* mosquitoes.

The tests were made by having one man wear shirts of different colors in mosquito-infested areas, while another man counted the number of mosquitoes alighting on them. The counts were made on the back of the shirt on the area enclosed by the side seams, the sleeve seams, the shoulder seams, and the belt line of the trousers.

The shirts were made of broadcloth. Seven different colors were tested—black, white, red, blue, green, yellow, and tan. Each shirt was tested for 4 minutes at a time. The counts recorded represent the largest number of mosquitoes present on the test area at any one time in each consecutive 30-second period. After eight such counts, a shirt of a different color was worn. The order in which the shirts were used was changed in each series of tests.

The tests were made in the shade, unless the sky was overcast. Several times during the season 10-minute collections of the females alighting on the collector's clothing were made to determine the species and their relative abundance.

The first tests were made in the Columbia and Willamette River bottoms where *Aëdes lateralis* (Meig.) was the predominating species. Ten-minute collections in these areas had shown that 99 per cent of the population was of this species, and the remaining 1 per cent *A. vexans* (Meig.) Other tests were made near Klamath Falls, Oregon, where the entire mosquito population was *A. dorsalis* (Meig.). A few tests were also made in meadows near Mt. Adams in Washington, where the mosquito population comprised about 51 per cent of *Aëdes hexodontus* Dyar, 26 per cent of *A. communis* (Deg.), and 23 per cent of *A. aboriginis* Dyar.

Table 1.—Mosquitoes counted in half-minute tests on different colored shirts worn in the field.

Color	*Aëdes lateralis** (176 tests per color)	*Aëdes dorsalis* (72 tests per color)	*Aëdes* spp. (32 tests per color)
Black	1499	131	309
Blue	1334	126	115
Red	1331	105	125
Tan	882	77	117
Green	863	92	86
Yellow	623	42	70
White	520	41	63
Total	7052	614	885

* 1 per cent of totals were *Aëdes vexans*.

The mosquito counts for all these tests are shown in table 1. Black was the most attractive color to all the species tested. The color preferences of *Aëdes lateralis*—black, blue, red, tan, green, yellow, and white in the order named—were similar to those of *A. dorsalis*—black, blue, red, green, tan, yellow, and white. Black was almost three times as attractive as white, and more than twice as attractive as yellow to *A. lateralis*.

[1] Richmond Program Paper.

[2] The writer wishes to thank H. H. Stage and W. W. Yates for assistance in making some of the tests, and F. M. Wadley for assistance with mathematical comparisons.

Significant differences in the color responses of *Aedes lateralis* occurred between all colors except red and blue, green and tan, and yellow and white, whereas with *A. dorsalis* and the mixed group of species they occurred only between black and the other colors tested.

These tests show that white or yellow clothing provides the greatest protection from mosquitoes in areas where the test species are present, and that black, blue, or red clothing provides little protection.

The spectral reflectances of the cloth in shirts used in these tests were determined with a *Beckman* spectrophotometer for the wave lengths from 254 to 1000 millimicrons.[2] Readings were taken at intervals of about 20 millimicrons throughout this range. The average spectral reflectances of these colors, based on the readings obtained in the visible range from 400 to 750 millimicrons, were black 3.41, blue 17.5, red 23.7, tan 37.3, green 34.4, yellow 49.9, and white 74.1. The color preferences of *Aëdes dorsalis* follow this same sequence of reflectances from black to white; those of *A. lateralis* follow the same sequence as the reflectances of the test colors in the 254 to 750 millimicron range. The reflectances of the test colors in this range are black 3.4, blue 17, red 19.6, tan 31.7, green 32.2, yellow 41.8, and white 66.6. The correlation between spectral reflectances and color preferences of these species suggest that they lack the ability to distinguish colors, and that colors are chosen on the basis of their spectral reflectances.

Aëdes lateralis is a dark colored mosquito and is least visible on black, for which it shows the greatest preference. *A. dorsalis*, on the other hand, is a gray mosquito, which makes it less visible against a background of the tan and red colors of this series than against a black background. The preference of *A. dorsalis* for black, in spite of its greater visibility against a background of that color, indicates that the reactions which govern its choice of colors are not based on protective coloration.

[2] These tests were made by the National Bureau of Standards. A freshly prepared magnesium oxide surface was used as the 100-per cent standard, and the reflectances of the seven samples were measured relative to it. Each sample was measured in a single thickness and was backed by a piece of white *Vitrolite* glass from 340 to 1000 millimicrons and by a piece of diffusing aluminum at 254 and 313 millimicrons.

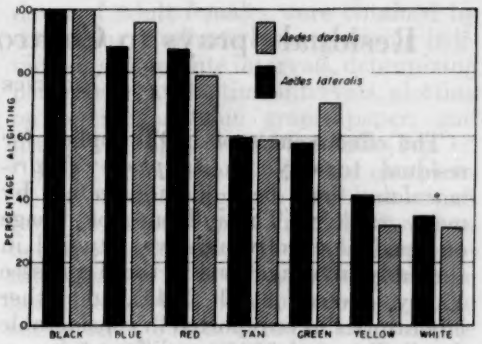

FIG. 1.—Color preferences of *Aëdes lateralis* and *A dorsalis*, as determined by the total numbers alighting on colored shirts. The degree of preference for each color is based on an assigned value of 100 per cent for the mosquitoes counted on a black shirt.

SUMMARY.—The effect of clothing color on the rate of attack of several species of *Aëdes* mosquitoes was tested. *A. lateralis* (Meig.) preferred black, blue, red, tan, green, yellow, and white in the order named, whereas *A. dorsalis* (Meig.) preferred black, blue, red, green, tan, yellow, and white. A group of mixed species consisting of *Aëdes hexodontus* (Dyer), *A. communis* (Deg.), and *A. aboriginis* Dyar preferred black, red, tan, blue, green, yellow, and white. Mosquito attack can be greatly reduced by the use of non-attractive clothing colors, such as white and yellow, in areas where these species are present.

The color preferences of *Aëdes dorsalis* follow the same sequence as the spectral reflectance values of the test colors in a wave-length range from 400 to 750 millimicrons, whereas the preferences of *A. lateralis* follow the sequence in the 254- to 750-millimicron range. These correlations suggest that colors are chosen on the basis of their spectral reflectances, and that these species lack the ability to distinguish colors.

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Residual Sprays to Control *Anopheles quadrimaculatus*

LAURENCE K. CUTKOMP[1]

The effectiveness of DDT applied for residual toxicity to *Anopheles quadrimaculatus* has been demonstrated by many workers. The influence of dosage on residual effectiveness was studied in the early investigations in the Tennessee Valley (Metcalf et al., 1945), and other laboratories have reported in considerable detail (Fya *et al.* 1945) on different dosage levels.

During the past two years (1945 and 1946) other phases of residual insecticide application have been studied by the Tennessee Valley Authority. In the laboratory, the effect of formulation, the influence of widely varying surfaces and a comparison of promising new chlorinated organic insecticides, have been investigated. Field studies have involved comparisons of these newer insecticides under similar conditions and to a certain extent their employment in varied conditions that exist in premise structures. The results reported are in the form of a progress report as several aspects of the work are continuous.

MATERIALS.—Three insecticides were used in the laboratory tests: DDT, benzene hexachloride (an equivalent quantity of the gamma isomer in technical 1, 2, 3, 4, 5, 6 hexachlorocyclohexane),[2] and *Velsicol 1068*[3] applied as solutions and emulsions using the solvent *Velsicol 2A* (a xylene substitute composed principally of isopropyl benzene). The emulsifier was a mixture of *Span 20 and Tween 20*[4] (sorbitan monolaurate and a polyoxyalkylene derivative of sorbitan monolaurate). There was evidence that DDT was more efficiently deposited on certain surfaces with aluminum stearate (Ebeling 1945), and the more readily available related compound zinc stearate was added to several of the formulations at the rate of 2 per cent. A wettable or dispersible DDT was also used.

Field tests over the 2-year period involved five materials in addition to DDT. They include pyrethrins, benzene hexachloride, a 90-per cent DDT-10 per cent benzene hexachloride mixture, and compounds chlordane[5] ($C_{10}H_6Cl_8$) and *Toxaphene* ($C_{10}H_{10}Cl_8$).[5] Tests have been made with a wallpaper prepared commercially with 125 mg. DDT per sq. ft. in the printed design.[6]

METHODS.—Laboratory tests have been carried out on 6-inch squares of Wall board and on clay and whitewash preparations applied on such boards. The clay preparations were red clay subsoil collected in the Wilson Dam, Alabama, area. Clay applications were at least a half inch in thickness, precluding any influence the wallboard might have upon the insecticide. Whitewash was brushed on the air-dried clay surface and the insecticide brushed uniformly on the dry surface of board, clay, or whitewash at the rate of 100 mg. per sq. ft. Ten to 20 female mosquitoes 3 days or less in age were confined under petri dishtops and tested as previously described (Metcalf & Wilson, 1945). Laboratory temperatures varied from 68° to 80° F. The criterion for knockdown consisted of a determination of the time when the mosquito could no longer right itself. Such morbidity-time values give valid comparisons and are valuable from the standpoint of mortality information since recoveries following knockdown with these test insecticides, with the exception of pyrethrins, are practically non-existent. Benzene hexachloride was tested with mosquitoes under a half-petri dish even though it is known that a new application exhibits vapor toxicity (Metcalf 1946). The time differences under screen and petri dishes were not great on newly treated boards, and the vapor toxicity does not affect knockdown values of well-aged applications.

Field tests consisted of applications of insecticide emulsions to two unoccupied experimental houses (Metcalf *et al.*, 1945) papered with heavy brown paper and to certain occupied houses, barns, and sheds. Knockdown values were obtained in the experimental papered houses by liberating

[1] Biology Staff, Malaria Control Division, Health and Safety Department, Tennessee Valley Authority, Wilson Dam, Alabama.

[2] The presence of other materials, particularly isomers, could be expected to influence the toxicity somewhat.

[3] Velsicol Corporation, Chicago, Illinois.

[4] Atlas Powder Company, Wilmington, Delaware.

[5] Hercules Powder Company, Wilmington, Delaware.

[6] United Wallpaper, Inc., Chicago, Illinois.

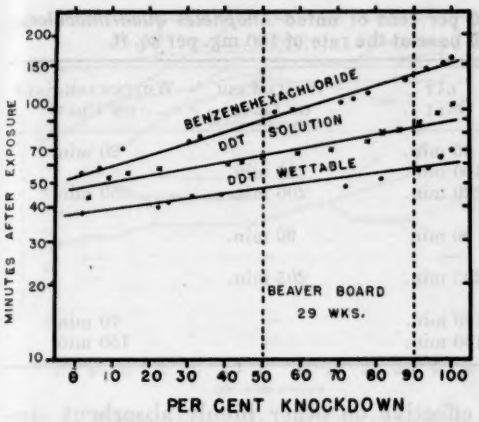

FIG. 1.—Example of method for determining knockdown values of female *Anopheles quadrimaculatus*. The comparison includes a benzene hexachloride solution, a DDT solution, and a DDT wettable, all having been applied to wall board 29 weeks before the test.

insectary or wild mosquitoes. Premise structures were near breeding areas and weekly mosquito inspections were carried out.

LABORATORY RESULTS.—The 100 mg. per sq. ft. dosage of the active ingredient was arbitrarily chosen since Metcalf *et al.* (1945) and Fay *et al.* (1945) had provided evidence that a range of from 50 to 300 mg. per sq. ft. produced little difference in the reaction of mosquitoes. Results of the laboratory tests carried out on wallboards squares are given in table 1. The times for 50 and 90 per cent knockdown of adult females were obtained by combining duplicate tests, grouping individuals at 2-minute intervals, determining percentages at the time intervals, plotting on semi-logarithmic graph paper, and fitting a straight line to the data (Fig. 1).

DDT preparations, with the exception of the emulsion-stearate combination, all produce more rapid knockdowns than benzene hexachloride or chlordane preparations at the 29 week test period. Benzene hexachloride had been more rapid in the earlier tests. The addition of zinc stearate to a DDT solution appeared of value through the 16-week test period, but at 29 weeks this increased effectiveness was not evident except with the combination of zinc stearate and *Velsicol 1068* emulsion. Zinc stearate appeared to be quite detrimental when in combination with a DDT emulsion. After aging, solutions of both DDT and *Velsicol 1068* gave more rapid knockdown values than the respective emulsions. DDT solutions and the wettable form of DDT gave about equally rapid knockdown through the 16-week period, but the wettable product was more rapid at 29 weeks. The slow action of the new application of DDT as a wettable dust spray has no ready explanation. Its comparatively rapid action at 29 and 30 weeks has been consistently demonstrated in a number of replications.

Results from the clay surface tests showed within one week that a *Velsicol 1068* emulsion or solution was not suit-

Table 1.—A comparison of several formulations of DDT, *Velsicol 1068*, and benzene hexachloride applied as residual sprays on wall board, Using unfed *Anopheles quadrimaculatus* females less than 72 Hrs. of Age. Application rate: 100 mg. per sq. ft.

		MINUTES FOR KNOCKDOWN OF 50 AND 90 PER CENT							
		New		1 Wk.		15 Wks.		29 Wks.	
INSECTICIDES	ADJUVANT	50	90	50	90	50	90	50	90
Wettable DDT	None	62	76	26	33	39	52	48	59
DDT Solution	None	43	54	46	58	30	37	64	90
DDT Solution	Zinc Stearate	30	39	32	39	26	32	71	99
DDT Emulsion	None	30	48	—	—	52	68	80	109
DDT Emulsion	Zinc Stearate	44	66	—	—	52	73	170	212
Benzene-hexachloride Solution	None	16[1]	21[1]	12	17	24	33	91	142
Benzene-hexachloride Solution	Zinc Stearate	17[1]	24[1]	13	16	24	33	91	134
Chlordane[2] Solution	None	37	44	55	65	43	58	160	220
Chlordane Solution	Zinc Stearate	42	48	65	77	50	71	205	235
Chlordane Emulsion	None	62	71	—	—	64	85	224	289
Chlordane Emulsion	Zinc Stearate	54	63	—	—	57	74	206	275

[1] Tested under screen eliminating fumigating action, but permitting untreated resting places.
[2] *Velsicol 1068*.

Table 2.—Approximate knockdown times for 50 per cent of unfed *Anopheles quadrimaculatus* females with *Velsicol 1068* applied on a clay sub-soil base at the rate of 100 mg. per sq. ft.

Formulation	Age of Application	Clay Only	Whitewash on Clay	Whitewash-Salt on Clay
Solution	24 hrs.	50 min.	—	20 min.
	72 hrs.	100 min.	95 min.	—
	1 wk.	220 min.	200 min.	250 min.
Solution and Zinc Stearate	24 hrs.	90 min.	90 min.	—
	48 hrs.	—	—	—
	1 wk.	295 min.	205 min.	—
Emulsion	48 hrs.	120 min.	—	70 min.
	1 wk.	130 min.	—	150 min.

able for residual application on this type of background (Table 2). Tests with *Velsicol 1068* on clay were discontinued after one week.

The relative effectiveness of benzene hexachloride and DDT as solutions and emulsions is reflected in the knockdown values obtained on clay surfaces (Table 3). All benzene hexachloride formulations were effective throughout, while DDT preparations had lost most of their effectiveness at the end of 25 weeks although the emulsion retained some toxicity. All knockdown values are greater than comparable materials applied to wall board squares. It should be noted that where DDT was most effective on the wall board squares benzene hexachloride gave superior results on the clay surfaces, including those with whitewash preparations. Based on values obtained, the salt in whitewash surface appeared to be most suited for the DDT emulsion and the benzene hexachloride solution. Whether benzene hexachloride would be more effective on other highly absorbent surfaces has not been shown. One possible explanation of DDT decomposition and loss of toxicity on clay might be that certain catalysts, such as iron, are present and have a lesser influence on the toxic qualities of benzene hexachloride. Gunther & Tow (1947) have shown that iron does not have such a marked catalytic action on benzene hexachloride. The parallel loss of DDT toxic action on a whitewash layer and a clay makes the explanation of a chemical catalytic decomposition somewhat less tenable, although it is not completely ruled out because of the porosity of the whitewash layer. The rapid loss of toxicity chlordane which is a liquid, was not unexpected.

Field Results.—Six materials have been tested for residual toxicity in the unoccupied experimental houses. Metcalf *et al.* (1945) have pointed out that occupied houses lost their toxicity more rapidly than uninhabited experimental houses. In viewing the results (Fig. 2),

Table 3.—A comparison of DDT and benzene hexachloride formulations applied to a clay subsoil base. Values are knockdown times for 50 per cent of unfed *Anopheles quadrimaculatus* females less than 72 hours old. Ninety per cent knockdown values are included at the 25-week period.

Insecticide Formulations	New			1 Month			25 Weeks					
							Clay		Whitewash		Salt-Whitewash	
	Clay	Whitewash	Salt-Whitewash	Clay	Whitewash	Salt-Whitewash	50%	90%	50%	90%	50%	90%
DDT												
Solution	0:42[1]	1:20	0:38	2:45	1:30[2]	2:05	>10:00	>15:00	>12:00	>20:00	>12:00	>20:00
Solution plus zinc stearate	0:35	1:05	—	1:45[1]	—	—	>15:00	>20:00	9:00	>12:00		—
Emulsion	0:48	—	1:15	2:00	—	1:50	8:40	>12:00	—	—	6:00	7:45
Benzene hexachloride												
Solution	0:12	0:27	0:11	0:15	0:18	0:12[1]	5:20	7:40	5:50	8:00	4:00	5:40
									>12:00	>15:00		
Solution plus zinc Stearate	0:19	0:14	—	—	—	—	—	—	2:50	4:30	—	—
Emulsion	0:12	—	0:10	0:14	—	0:12	1:06	2:20	—	—	1:04	2:00
Control	20 to 24 hrs. on above untreated surfaces.											

[1] Time values are hours and minutes.
[2] Tested at 3 wks.

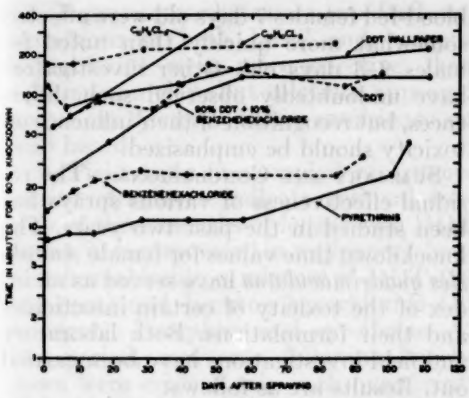

FIG. 2.—Residual toxicity to *Anopheles quadrimaculatus* of different materials applied in unoccupied experimental houses. The wallpaper contained DDT in the printing at the rate of 125 mg./sq. ft. and was applied in an occupied house. Other rates of application in mgs. per sq. ft. follow: DDT—250, $C_{10}H_6Cl_8$—170, $C_{10}H_{10}Cl_8$—160, DDT-benzene hexachloride—103, benzene hexachloride—100, and pyrethrins—200. Benzene hexachloride tested at 1 year gave 100 per cent knockdown and 100 per cent mortality in less than 240 minutes. The pyrethrins residual was ineffective a year after application.

it should be borne in mind that the insecticides were under very favorable conditions in unoccupied houses. The pyrethrin spray is outstanding with 100 per cent knockdown in less than 2 months, but this material is subject to oxidation when exposed to light and air circulation, both of which are minimized in these experimental houses since they are closed except during each testing period. As mentioned previously, recovery following knockdown is evident with pyrethrins. This recovery becomes greater as the treatment ages. The rapid knockdown time with benzene hexachloride over at least a 3-month period is quite evident, and this material exhibited complete knockdown with 100 per cent mortality a year after application in an unoccupied house. Pyrethrins gave no evident toxicity at the end of a year. Field observations in occupied houses (qualitative only) have indicated that the toxic effects of DDT to mosquitoes and flies persist more than a year after application. The addition of 10 per cent of the gamma isomer of technical benzene hexachloride to a DDT spray was effective in increasing the rapidity of the toxic effects over an 8-week period, but at 16 weeks this mixture had about the same speed of toxic action as DDT alone. The use of this combination may not be practical if it is allowed to stand for a period of time as Gunther & Tow (1947) have found that materials in technical benzene hexachloride decompose DDT, at least when heated. *Toxaphene* produced rather slow initial knockdown times but its persistence over a 12-week period compares very favorably with other residual applications. The comparisons (Fig. 2) must be viewed with certain reservations, particularly noting the fact that the dosages are not equal. The importance of dosage rate deserves further study.

The results obtained in an occupied house where walls were papered with wallpaper containing DDT (125 mg. per sq. ft.) in the printed design are included in figure 2. This preparation compares quite well with DDT sprays although its action appears somewhat slower.

Chlordane applied as a residual spray to six barns or sheds produced a marked reduction in resting *Anopheles quadrimaculatus*, but the effect was not as prolonged or as complete as obtained with DDT sprays in nearby areas (Table 4).

Table 4.—Season inspection records in treated barns showing actual counts of *Anopheles quadrimaculatus* mosquitoes before and after an insecticidal application at a rate of 200 mg. per sq. ft.

MATERIAL	BEFORE TREATMENT[1]	AFTER TREATMENT INSPECTIONS			
		New	1 Mo.	2 Mos.	3 Mos.
DDT	100	0	0	0	1
DDT	500	1	0	1	2
Chlordane	26	0	5	9	—
Chlordane	12	0	0	16	—
Chlordane	10	0	17	2	—
Chlordane	190[2]	0	130	106	—
Untreated	50	75	22	66	349
Untreated	16	65	98	102	370

[1] DDT sprays applied May 22 and May 27; chlordane sprays applied July 5.
[2] Residual spray applied to hog shed with all-metal roof and walls.

Although there is wide variation in untreated barns, the above two were selected as fairly representative in showing the relative abundance of mosquitoes throughout the season. The results reveal the ineffectiveness of the chlordane spray a week after application on an all-metal shed.

One comparative study involving the reaction patterns of adult mosquitoes to residual insecticides is obtained from per-

centages of mosquitoes leaving the experimental house during the test period. Metcalf *et al.* (1945) studied this type of irritant effect exhibited by DDT, and it is of interest to compare other residual insecticides with DDT. Table 5 shows the contrasts between compounds applied in the unoccupied experimental houses. Toxaphene produced relatively little change

Table 5.—Influence of residual insecticides on activity of *Anopheles quadrimaculatus* mosquitoes liberated in the experimental houses.

Insecticide	Application Rate Mg./Sq.Ft.	Days After Spraying	Total Mosquitoes	Per Cent Leaving House
DDT	250	86	460	57
Pyrethrins	200	100	249	80
Benzene hexachloride	100	91	264	8.3
90% DDT–10% Benzene hexachloride	103	17	117	8.5
Toxaphene	160	84	514	3.5

in the activities of mosquitoes until they were affected severely enough to be unable to maintain their normal resting positions. Many mosquitoes subjected to this material continued their biting and blood-seeking habits. With DDT a large percentage of the mosquitoes show a partial reversal of phototropic responses and seek an area with more light. Such a response did not take place with benzenehexachloride since the percentage leaving the treated house was low.

Biological Factors.—Observations indicating differences in susceptibility and resistance of *Anopheles quadrimaculatus* have been obtained during these studies. The greater susceptibility of males to insecticides in the experimental houses (Fig. 3) is evident in insectary-reared and wild mosquitoes. Tarzwell & Stierli (1945) had pointed out this difference with DDT residual surfaces. Other biological variations which appear consistent with both DDT and benzene hexachloride are in agreement with the findings of David (1946) who has made a rather complete study of the reactions of *Aëdes aegypti* subjected to DDT and pyrethrum space sprays. The differences noted in the present study have included: (1) females fed on blood for from 3 to 24 hours before testing were not affected as rapidly as females of the same age fed on sugar water; (2) females which had emerged for 7 days and were not blood fed were more quickly affected than unfed females 1 to 3 days old; and (3) blood-fed females 7 days old were affected somewhat more quickly than unfed females 2–3 days old. Other investigators have undoubtedly observed such differences, but recognition of their influence on toxicity should be emphasized.

Summary and Conclusions.—The residual effectiveness of various sprays has been studied in the past two years. The knockdown time values for female *Anopheles quadrimaculatus* have served as an index of the toxicity of certain insecticides and their formulations. Both laboratory and field investigations have been carried out. Results are as follows:

1. The type of surface for residual insecticide application is highly important. At the end of 29 weeks DDT was more effective than benzene hexachloride or chlordane applied on a beaver wall board. Benzene xheachloride had produced more rapid toxic effects than DDT when res-

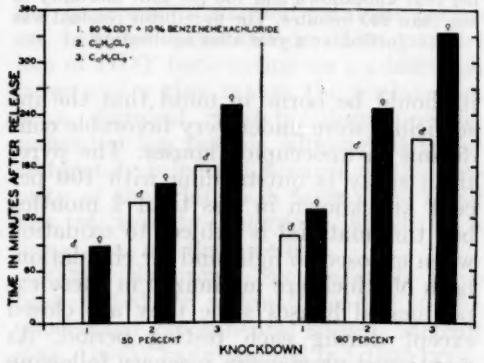

Fig. 3.—A comparison of knockdown values for both sexes of *Anopheles quadrimaculatus* tested with three different spray residues applied in unoccupied experimental houses. Age of residues at testing period was as follows: DDT-benzene hexachloride—57 days, $C_{10}H_{10}Cl_8$—84 days, $C_{10}H_6Cl_8$—38 days. Wild mosquitoes were used except with $C_{10}H_{10}Cl_8$ where insectary-reared mosquitoes were employed.

idues were not so old. On a clay subsoil surface DDT formulations were not as effective as benzene hexachloride. The toxicity of *Velsicol 1068* on clay was very low after one week. All three materials were much more effective on wall board than on clay.

2. The formulations of insecticides did not appear to be as important as the compounds under test. The wettable or dispersible type of DDT and solutions of DDT and benzene hexachloride did not differ markedly through a 16-week period on wall board, 29 weeks the wettable

DDT gave somewhat more rapid effects. Emulsions of both DDT and benzene hexachloride were more effective than solutions on clay, but solutions appeared more satisfactory than emulsions on wall board.

3. Field tests in occupied and unoccupied structures indicate residual toxicity of three months or longer with DDT (spray or incorporated in wallpaper), benzene hexachloride, a mixture of DDT (90 per cent) and benzene hexachloride (10 per cent), *Toxaphene* and pyrethrins. At this period, recoveries following knockdown were evident only with pyrethrins. *Velsicol 1068* may be effective for this period under certain conditions. Pyrethrins and benzene hexachloride produced the most rapid knockdown through the 3-month test period. Under certain conditions both DDT and benzene hexachloride exhibit residual toxicity for one year or more. This prolonged residual effect has not been shown by pyrethrins or *Velsicol 1068* 4. The reaction patterns differed when mosquitoes were exposed to DDT, *Toxaphene*, and benzene hexachloride. The irritant effect produced by DDT is much less apparent with *Toxaphene.*

5. All test materials produced more rapid effects on male mosquitoes. Observations on other biological factors indicate that older females are more susceptible than younger ones and also that mosquitoes without a blood meal are more susceptible than blood-fed specimens.[1]—1-16-47.

[1] ACKNOWLEDGMENTS. The advice and assistance of members of the Biology Staff have been greatly appreciated throughout this study. Advice and enthusiastic support have been given by Dr. A. D. Hess. Dr. R. L. Metcalf, former staff member, carried out studies cited during 1945 providing information for several comparisons which otherwise could not have been made. Considerable assistance in spraying operations and collection of data have been made by Mr. Gene Lasater. Messrs. Roy Thorn, Arthur Morris, and George G. Keener, Jr. also assisted in certain phases of the work.

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Nosema Losses in Package Bees as Related to Queen Supersedure and Honey Yields[1]

C. L. FARRAR, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*[2]

Beekeepers in the North depend on package bees from the South to increase their number of colonies or to replace winter losses. A few prefer to restock apiaries with package bees rather than attempt to overwinter colonies. Each year there are thousands of new beekeepers who use package bees to start colonies. In 1945 there were 479,085 packages (1.25 million pounds of bees) and 874,600 queens shipped from the southern States and California. For several years the demand for bees and queens has exceeded the supply during April and May, the period when new colonies can be established most profitably.

The growth of the package-bee industry during the last 25 years attests the importance of packages in modern beekeeping. The need for more bees to provide for the pollination of agricultural crops in-

[1] Richmond Program Paper.

[2] In cooperation with the Wisconsin Agricultural Experiment Station.

Table 1.—Queen losses due to abnormal supersedure 1938 to 1946.

Year	Number of Packages	Queens Lost			Nosema-Infected Queens	Queens Not Found, Probably Infected
		First 2 Weeks	Second 2 Weeks	Second Month		
1938	143	5	7	8	No observations	
1939	130	2	4	5		
1940	220	6	16	18		
1941	150	11	18	9	3	
1942	180	3	9	14	11	7
1943	167	11	9	11	14	12
1944	170	22	52	12	48	35
1945	190	7	3	3	7	3
1946	190	4	7	6	10	5
Total	1,540	71	125	86	93	62
1942–1946		47	80	46	90	62

sures an expanding demand for some time to come. The productive performance of package colonies, however, has been extremely variable. In too many shipments there are heavy losses through queen supersedure, poor stock, or delayed delivery. Furthermore, the buyer often fails to provide adequate pollen and honey to support the brood rearing necessary for building large colonies.

Queen supersedure was recognized as a critical problem in the early development of the package-bee industry, and in 1935 a Federal project on supersedure was started to investigate causes and remedial measures. Experiments were set up to test many theories that had been advanced by beekeepers. By 1938 the conclusion was drawn that quality of stock was a major factor in supersedure, since the loss of queens was proportionately lower among stock groups showing high productivity and higher among those showing low productivity, based upon honey yields obtained from the colonies headed by surviving sister queens (Farrar & Schaefer 1939). This was a fortunate conclusion even though it has since been proved erroneous. It focused attention on stock characteristics and the opportunity for improvement through selection and breeding. Some of the poorest queens tested have not been superseded, whereas not infrequently outstanding queens, judged by the quality and quantity of their brood, suddenly stopped laying and were lost.

In later Federal work Nosema disease was shown to be largely responsible for the abnormal supersedure of queens in package colonies (Farrar 1942; 1944). Even though a queen may escape infection, the development of the colony is retarded more or less in proportion to the degree of infection in the original package population. The purpose of this paper is to summarize the evidence found against the protozoan *Nosema apis*, particularly as it relates to package bees.

QUEEN LOSSES AMONG PACKAGE BEES.—Most queen losses may be grouped into five categories: (1) Introduction losses, (2) abnormal and drone-laying queens, (3) abnormal supersedure of queens that lay normally, (4) accidental loss during hive manipulations, and (5) the normal supersedure of failing or worn-out queens. The abnormal supersedure is most serious and may extend through the first 2 months after the packages are established. Although the association between Nosema and the abnormal supersedure of queens was not established until 1941, the queen losses for the period 1938 to 1946 are recorded in table 1.

The first queens examined for Nosema infection were removed from their colonies in June 1941. They had laid normally for about 2 months, but suddenly stopped laying, became sluggish, and most of their last eggs shriveled and failed to hatch. All were found to be heavily infected with Nosema. Previously, many queens had been observed to manifest similar symptoms, but the superseded queens either were not found or they were not examined for Nosema. Since the spring of 1942 an effort has been made to recover as many superseded queens as possible and to associate colony symptoms where the

queens were not found with those characteristic of supersedures where the queens were found infected. During the 9-year period approximately 18 per cent of the queens used were superseded abnormally. Investigations of the problem since 1942 indicate that at least 88 per cent of this loss can be attributed to the infection of the queen by the protozoan *Nosema apis*.

NOSEMA-INOCULATED QUEENS.—In the course of these investigations, queens that were allowed to feed on sugar sirup containing five or six spores per microscopic field (400X) manifested symptoms identical to those exhibited by queens naturally infected prior to supersedure. The inoculated queens appeared to lay normally for a period of 1 to 7 weeks. The infected queens then suddenly stopped laying, and many of the last eggs shriveled and failed to hatch.

Occasionally a colony is unable to start queen cells because the last eggs fail to hatch and the larvae present in the colony are too old to be developed into queens. The infected queen becomes sluggish and may remain in the hive several days before death, or she may crawl out of the hive, as evidenced by her position to one side of or even back of the hive. When carried out by the bees, she usually is found in front within a distance of 6 feet. A sluggish queen, upon dissection, shows a typical swollen milky-white ventriculus containing millions of Nosema spores, when a smear is examined under the microscope (Fig. 1).

On February 1, 1944, 13 queens were removed from colonies and allowed to feed on inoculated sirup for at least an hour. They were then supplied with uncontaminated sirup. Of 5 queens that were caged without attendants, 4 died on the 11th day and 1 was in a weakened condition. All 5 queens showed infection when smears of the ventriculus were examined. The eight other queens were provided with young atttendant bees and were successfully introduced into colonies on February 18. One queen was superseded about February 25. The others laid for varying periods up to March 13, when they were examined and found infected. Three queens had a few scattered eggs and sealed cells but no larvae, in contrast to the active brood rearing in similar colonies headed by uninoculated queens. A normal queen that was substituted in one of the colonies on March 13 had 2.5 frames of normal brood 12 days later.

Early in August, 45 queens were removed from their colonies and caged individually on dry comb under push-in cages. One cell filled with the inoculated sirup was available for each queen. The unattended queens were returned to their colonies after they had been observed to feed on the sirup. Five packages of bees were sprayed with the inoculated sirup and the next day were installed in hives with young queens just starting to lay. One of the inoculated queens was lost through manipulation, but 33 of the other 49 in the two lots were superseded within 10 to 30 days, 13 were superseded within 31 to 46 days, and 3 excaped infection. The latter showed no spores when examined after 9 weeks. The five queens added to the inoculated package bees became infected and were among those superseded within the first 30 days.

NOSEMA-INFECTED ATTENDANT BEES IN QUEEN CAGES.—In 1945, 34 out of 39 queens from two commercial sources were accompanied by one or more infected attendant bees. In 1946, 41 out of 62 cages from commercial sources showed from 1 to 5 infected attendants, and 1 infected queen was found. Other miscellaneous shipments of queens have shown infected attendants, and an occasional queen dead on arrival has been found infected. However, other causes, particularly overheating, are more likely to be responsible for losses during the short period queens are in the mail.

In an attempt to reduce the danger of including infected attendant bees, queens from the Southern States Bee Culture Laboratory were provided with attendants taken from a colony that had been moved twice at 2-day intervals to eliminate field bees. Only a single infected attendant was found in each of 2 cages out of 28 received. This is in decided contrast to findings among other shipments of queens from that laboratory when the precautions for eliminating field bees had not been taken.

NOSEMA IN SOUTHERN COLONIES AND NUCLEI.—Nosema appears to be as widespread in southern as in northern apiaries. Every shipment of package-bees examined, regardless of the originating state

or source, has shown some Nosema infection when sampled upon arrival. The degree of infection among lots, even from the same source, has varied from negligible to 100 per cent.

Eight apiaries in Mississippi, Louisiana, and Alabama were visited in March 1945. Nosema-infected bees were found in small samples taken from 51 per cent of 65 colonies and 65 per cent of 123 nuclei. The colonies and nuclei were sampled at random, no effort being made to sample those in poor condition. In one queen-mating yard all the samples taken from 11 nuclei started with package bees without brood showed infection, whereas only 7 out of 15 showed infection where a comb of sealed brood had been added. The presence of brood did not eliminate the infection, but it decreased the proportionate number of infected bees by the addition of young emerging bees.

INCIDENCE OF NOSEMA AMONG PACKAGES.—Since 1942, samples of 10 to 15 live bees have been dipped from the cluster of each package upon arrival and examined in mass for Nosema infection. Since the samples represent only approximately 0.1 per cent of the total number of bees in a package, a negative sample does not necessarily indicate the absence of infected bees in a package.

The 1945 and 1946 package populations were again sampled during the third week after introduction just prior to the emergence of the first young bees. To determine the percentage of infection in the colonies, from 10 to 40 individual bees from each were examined. The percentage of infected to noninfected bees varied greatly among the colonies, some showing 100 per cent. The percentages of infected samples from packages on arrival, and from the colony populations, are given in table 2.

Table 2.—Nosema infection in package bees.

YEAR	PACKAGES	INFECTED SAMPLES	
		On Arrival	After 3 Weeks
	Number	*Per Cent*	*Per Cent*
1942	180	90	
1943	167	52	No observation
1944	170	62	
1945	190	30	90
1946	190	32	74

EFFECT OF NOSEMA ON BROOD PRODUCTION.—When the area of sealed brood measured 3 weeks after introduction, was correlated with the percentage of Nosema infection during the third week, negative correlation coefficients of −0.31 and −0.42 were obtained, respectively, in 1945 and 1946 for approximately 190 colonies each year. These data indicate that the presence of Nosema had a depressing effect on brood rearing somewhat proportional to the percentage of Nosema infection among the worker bees. Colonies showing infection of 60 to 100 per cent had an average of 100 to 125 square inches less brood than colonies showing 10 per cent or less infection. Variations in the number and age of bees making up each package, as well as in the productivity of the queens, obviously lowered the association between measured brood and degree of infection.

EFFECT OF NOSEMA ON HONEY YIELDS.—The honey yields from the package colonies varied with the degree of Nosema infection in the package populations 3

Table 3.—Average honey yields of package-bee colonies with different percentages of Nosema infection 3 weeks after installation.

YEAR	0 TO 10 PER CENT		20 TO 50 PER CENT		60 TO 100 PER CENT	
	Original Queen	Supersedure Replacement Queen	Original Queen	Supersedure Replacement Queen	Original Queen	Supersedure Replacement Queen
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
1945	267 (37)[1]	182 (25)	244 (50)	179 (50)	213 (12)	156 (13)
1946	9 (60)	−12 (20)	0 (33)	8 (10)	−2 (47)	−8 (14)
1946[2]	20 (38)	3 (5)	5 (24)	8 (9)	−3 (44)	−8 (14)

[1] Numbers in parentheses refer to number of colonies.
[2] 1 yard omitted.

weeks after the packages were installed.

Colonies in the low-infection group that retained their original queens averaged 54 pounds more surplus honey in 1945 than those in the high-infection group. They averaged 111 pounds more honey than the colonies in the high-infection group that superseded or had their queens replaced. The queen losses in the high-infection group were due largely to the queens themselves becoming infected.

No major honey flow developed in 1946; so the yields are given in gains or losses of honey above the reserve stores provided in the spring (190 packages averaged +0.9 lb.). One apirary location having the poorest honey flow was represented by 40 colonies in the low-infection group while there were only 10 in the intermediate—and 1 in the high-infection classes. Omitting the colonies of this yard, 38 colonies in the low-infection group that retained their original queens produced 23 pounds more honey than 44 colonies in the high-infection group, and 28 pounds more than colonies in the latter group that superseded or had their queens replaced.

DISCUSSION.—Nosema disease is so widespread in both the North and the South that users of package bees must anticipate losses in queens and in productive efficiency of the colonies. Fundamental studies are urgently needed, both of the organism *Nosema apis* and of its parasitism in the honey-bee.

The importance of Nosema in productive beekeeping has been overlooked, because the organism seldom causes death of the colony. It reduces the length of the life of the individual bee or queen. Throughout the beekeeping industry the losses, measured by reduced production, attributable to Nosema may equal or exceed those caused by the better known brood diseases.

Beekeepers who use package bees can reduce their losses by maintaining reserve queens in nuclei for prompt replacement of those superseded. Package colonies must be provided with adequate honey and pollen reserves, since a rapid addition of young bees will decrease the percentage of infection within the colony. Adding combs of brood from strong overwintered colonies to packages should be helpful for the same reason. Colonies located in full sunlight suffer less from Nosema than do those in the shade. Sunlight stimulates the flight of bees, and those weakened by Nosema are less likely to return to the hive.

Producers of package bees and queens should adopt practices that will decrease the chances of queen infection while in the mating nuclei or during shipment. A greater effort should be made to stock nuclei with only young bees and to provide them with brood. Each queen should be allowed to lay sufficient eggs to assure more or less continuous emergence of young bees. To accomplish this, somewhat larger nucleus hives may have to be substituted for the usual "baby" nucleus. Attendant bees for queen cages should be taken from a colony so manipulated as to free it of the older bees, rather than from the nuclei.

Colonies operated for package-bee production should be managed so that brood rearing will be maintained at a high level. Packages filled by shaking the bees from brood combs onto a queen excluder in the top of an open-type funnel probably will contain fewer infected bees than when the deep-type funnel is used. The older bees tend to fly off of the excluder, whereas the younger bees crawl through and can be shaken into the package. The smoke-up method now in general use includes both old and young bees indiscriminately and may result in a high Nosema infection.

Other operating factors will contribute to variations in Nosema infections among the bees shipped from any one source. The degree of infection is not necessarily uniform among the colonies in an apiary. The weather conditions at the time of shaking influence the percentage of field bees that may be away from the hive. Colonies that have been shaken one or more times probably will contain fewer old bees. The shaking method employed will affect the subsequent balance between the old and young age groups. The honey-flow conditions prior to and during the shaking season appear important. Nosema-infected bees manifest the crawling symptoms at the beginning of a heavy honey flow. The weak, infected bees presumably are unable to handle large quantities of nectar, and are therefore lost more rapidly from the hive than at any other time.—12–11–46.

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Sulfathiazole for American Foul Brood Disease of Honey-bees: Second Report[1,2,3]

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In the fall of 1945, the writers reported (Johnson & Stadel 1945) on one season of work with sulfathiazole for the control of American foul brood of honey-bees. Eight colonies with the disease were used in the experiments. Seven of these received treatment and one served as an untreated control. Sulfathiazole, purchased in the tablet form, was used at the rate of 0.5 gram to one gallon of sugar and water (mixture 1 to 1 by volume) or in water alone. The sulfathiazole-sugar-water mixture in every case was fed directly to the colonies, while the sulfathiazole-water mixture, though likewise fed, was in one case sprayed directly onto the brood frames at weekly intervals.

All the colonies receiving sulfathiazole in 1945, regardless of the method of treatment, responded favorably. Every colony receiving the sulfathiazole-sugar-water mixture, and these included hives 1 through 6 inclusive, eliminated all visual evidence of the disease before the last of the brood emerged in the fall. A small number of dead diseased larvae were still being found in colony 7 which had been sprayed at weekly intervals with the sulfathiazole-water mixture. The untreated control was weakened to such an extent by the disease that it was fumigated in the first week of October and removed from the apiary.

As the fall season was very short, the remaining colonies were prepared for winter by reducing the size of the entrances, removing all supers and leaving only the brood and food chambers. More than 50 pounds of honey were left in each hive for winter stores. Winter packing consisted of placing a shallow super containing a burlap bag partially filled with dry leaves over the inner cover of each hive. All the colonies wintered successfully.

The season of 1946 opened unusually early with an extended period of warm weather. As a result, when the first spring inspection was made on March 14, 1946, it was found that heavy brood rearing was already in progress and was creating a serious demand on the stores. This demand necessitated feeding hives 1 and 5. Each hive was fed a total of 7 quarts of sugar and water containing 0.5 gram of sulfathiazole per gallon of mixture, in two separate feedings. No additional feeding in the spring was required by these two hives or by any of the others treated in 1945.

Seasonal hive conditions in respect to the disease were observed by making thorough examinations of each at approximately 3-week intervals instead of 2-week intervals as in 1945. No signs of foul brood were observed in hives 1, 5, and 6 during the entire season of 1946. A few old scales which had been covered with stores were observed in hive 4 on April 30. These scales were removed by the bees before the next observation and no other indications of disease were seen during the remainder of the season. Hives 1 and 6 were in good condition throughout the season although supercedure had taken place in each. Hive 1 produced 25 pounds and hive 6 approximately 50 pounds of surplus honey.

Hives 4 and 5 were in poor condition practically all season. The queen in hive 4 had become a drone layer. Hive 5 was queenless. The first requeening effort in both hives was unsuccessful. Worker drone layers and requeening troubles were experienced until past mid-summer. Hive 5 began to improve in August and hive 4 in September. Hive 5 should winter suc-

[1] Richmond Program Papers.

[2] The first section of this report deals with results obtained in 1946 in hives treated with sulfathiazole in 1945.

[3] Roy Stadel collaborated in the project.

cessfully, while hive 4 may be called questionable. Regardless of the loss of queens, small numbers of young bees and general weakness, disease did not appear in these two hives. Neither hive produced any surplus honey.

Hive 2, which was badly diseased and contained about one frame of bees when received in 1945, wintered in very good condition. Two diseased cells were found in one frame in the food chamber which contained some brood on May 31, 1946. The frame concerned had been nearly full of scales the preceding season. Although the disease increased in the food chamber, no disease was found in the brood chamber until the middle of July. By the first week in August there were over 50 diseased cells in the brood chamber but none was observed among the frames in the food chamber which was becoming filled with honey. On October 8, 1946, considerable disease was found in five frames of the brood chamber and a few diseased cells were located in one frame in the food chamber. No scales were observed at any time during the season. Hive 2 was strong in bees all through 1946 and it produced 60 pounds of surplus honey. Resumption of treatment with sulfathiazole began on October 16, 1946.

Hive 3 entered the season of 1946 without any indication of disease. On May 31 five cells of American foul brood disease were found. At the next examination on June 24, a few dead larvae were found in open cells. These were not typical of American foul brood. On July 16, one diseased cell was found while none was found on August 5. Five diseased cells were found in two frames on August 26. No other disease was observed in this hive for the remainder of the season. Hive 3 was in excellent condition all through the season and produced 70 pounds of surplus honey.

Hive 7 (brood frames sprayed weekly with sulfathiazole and water) entered the season of 1946 without any evidence of American foul brood. However, on May 31, there were 19 diseased cells found in the food chamber and 13 in the brood chamber. The hive was strong in bees and required an extra super for expansion. As the season progressed, the amount of disease increased, with scales observed on July 16. Though the number of diseased cells continued to increase, no other scales were observed until October 8, when a few more were observed in another frame in the brood chamber. Hive 7, although containing a serious infection of American foul brood disease during most of the season, produced 50 pounds of surplus honey. Treatment with the sulfathiazole-sugar-water mixture was begun on October 14, 1946. This hive entered the winter well populated with bees.

Conclusions. At the end of 2 years of study of seven colonies infected with American foul brood disease, housed in hives consisting of multiple body sections, and medicated with 0.5 gram of sulfathiazole to 1 gallon of sugar and water mixed 1 to 1 by volume, it is concluded that:

1. Medication with sulfathiazole eliminates all visual evidence of the disease in the brood regardless of the extent of the causal organism in the hive.

2. The incidence of disease and the condition of the hive are the most important factors affecting the results of the treatment.

3. Treatment with sulfathiazole should begin as soon as possible after the first indication of disease.

4. The data obtained to date indicate that prolonged treatment until the disease is no longer visually evident may eliminate the disease in some hives.

5. The data obtained to date also indicate that the greater the incidence of disease, the greater the risk in assuming the disease has been eliminated by the first prolonged treatment.

6. Follow-up treatments in the fall and especially in the spring should be practised.

7. Treatment with sulfathiazole is not a simple procedure that can be performed blindly. It must be systematic and weighed according to the local situation.

Results obtained in 1946 with medications of sulfathiazole, other sulfa compounds, penicillin, furacin and X-ray for American foul brood disease are discussed on the following pages.

In September 1945, hive 8, with a standard hive body and deep food chamber, badly infected with American foul brood disease, but well populated with bees, was obtained for the experimental apiary. Sulfathiazole, 0.5 gram in a gallon of sugar and water mixture (1 to 1 by volume) was fed to this colony on September 24, 1945, and continued until late

in November. The treatment was resumed in March of 1946 with the last feeding made on July 31, 1946. During the winter mice succeeded in entering the hive and damaged three frames in the brood chamber. Brood rearing began early in the spring and on April 23, four frames of healthy open and sealed brood were observed in the food chamber. The brood chamber had not been used as yet for brood rearing. On May 31, 1946, as the food chamber was becoming crowded it was replaced with the brood chamber. The bees had not been very active in cleaning out the scales and other debris in the brood chamber until the change was made. All scales in both chambers were removed by July 16. Only 5 newly diseased cells were found in this hive during 1946 and the last of these was observed on July 16. A total of 8.33 gallons of the sulfathiazole mixture was fed to this hive. Approximately two gallons were fed in the fall of 1945 and the remainder in 1946. All the material was fed from cans placed above the inner cover and protected by an empty super and top cover, excepting the last three quarts which were fed in a *Boardman* feeder. This colony produced about 30 pounds of surplus honey.

Hive 9, infected with American foul brood disease, was secured late in May, 1946. It consisted of a standard hive body moderately populated with bees and a deep food chamber containing new frames and foundation. The disease was in an advanced stage and scales were very numerous in the hive body. Treatment with sulfathiazole, 0.5 gram to 1 gallon of sugar and water, was begun on May 31, 1946. A total of 49 quarts was given to this hive. the first 33 quarts were fed through the medium of cans placed on the inner cover and the rest in a *Boardman* feeder. The last treatment was made on September 9. At each successive observation it was noted that the conditions in the hive had improved. The foundation in the food chamber had been completely drawn and filled with brood (two frames) and honey (eight frames) by July 16. The last scale was observed on August 5 and there were no visual indications of diseased cells after August 26. No disease was observed in the food chamber at any time during the entire season. This hive produced approximately 15 pounds of surplus honey.

On May 28, 1946, package bees, each containing a laying queen, were introduced into three badly diseased hives numbered 14, 15, and 16. These hives formerly contained bees which were fumigated or failed to winter because of their weakened condition. All were of the standard type and hive 14 included a deep food chamber, hive 15 just a brood body, and hive 16 a shallow food chamber. Sulfathiazole 0.5 gram, 1.0 gram and 2.0 grams, respectively, in 1 gallon of sugar and water mixed 1 to 1 by volume was fed to the individual hives beginning May 31. Hive 14 received a total of 58 quarts of the 0.5 gram mixture, hive 15 a total of 63 quarts of the 1.0 gram mixture, hive 16 a total of 63 quarts of the 2.0 gram mixture. Immediately upon their introduction into the hives the package bees began to remove the scales and debris. All scales were eliminated from these hives by June 24, while two diseased cells were found in hive 14. At the next observation on July 16, hive 14 contained two diseased cells. No other evidence of disease was observed in any of the hives after that date. Each of these hives received its last treatment on September 3. Hive 14 did not produce any surplus honey; hive 15 produced 30 pounds; and hive 16, 11 pounds. All were in excellent condition for wintering.

Hives 10 and 11, infected with American foul brood disease, were secured for experimental work during the second week in July, 1946. Both were standard double-walled hives. Hive 10 was composed of a brood chamber, a shallow food chamber nearly full of honey and an empty shallow super, moderately populated with bees. Hive 11 was composed of a brood chamber, a shallow food chamber with considerable honey and a super practically full of capped honey, well populated with bees. Beginning July 16, these hives were fed with furacin, one of the newer bacteriostatic compounds (5-nitro 2-furaldehyde semicarbazone) at the rate of 0.5 gram to one gallon of sugar and water mixed 1 to 1 by volume. Hive 10 received 13 pints supplied in a can placed over the inner cover and 11 a total of 6 pints by *Boardman* feeder. The disease increased rapidly in these hives with a resulting decrease in the morale of the bees. As a result the treatment was changed to sodium sulfathiazole on August 5. Hive 10 received a total of 7 quarts of sugar and

water (1 to 1 by volume) containing sodium sulfathiazole at the rate of 0.5 gram per gallon and 4 pints of this were fed in a Boardman feeder. This colony had deteriorated so badly that it was not able to improve. It was fumigated with cyanide on September 17. Hive 11 received a total of 8 quarts of the sodium sulfathiazole-sugar-water mixture. The quart jar in the feeder was refilled at weekly intervals excepting the period of September 17 through October 15. This exception was made to give the colony an opportunity to center its activity on gathering natural winter stores during a heavy goldenrod nectar flow. Medication was resumed on October 16 and the last treatment was made on October 29. Hive 11 improved rapidly after feeding it sodium sulfathiazole and on September 17 less than 25 diseased cells were observed in the hive. However, on October 8 there were a large number of diseased cells approaching the scale stage. This upsurge of the disease late in the season, in all probability, was due to the omission of the treatment during the goldenrod nectar flow. This colony produced a total of over 40 pounds of surplus honey during the season.

Hives 17, 18, and 19 were a series of three in an experiment to determine the effect of soaking American foul brood infected frames in water containing small amounts of sulfathiazole. Hive 17 was the control of this experiment and served as a sugar and water fed control for the entire experimental apiary. It was composed of a new, complete, one-story standard hive containing six badly diseased frames and 4 new frames with foundations. Hives 18 and 19 were similar in composition, but the six diseased frames in each had been treated by submerging them in two separate baths, containing 0.5 and 1.0 grams per gallon of water respectively, at room temperature for one week. As this experiment was begun on July 15, which was comparatively late in the season, each hive received a 5-pound package of bees with a laying queen. Each hive was given a total of 6 quarts of sugar and water mixed 1 to 1 by volume in two feedings, the first on July 16 and the second on July 31. The introductions were successful and the bees in each colony immediately began to remove the scales and debris. Eggs or newly hatched larvae were observed in each of the hives on July 16. When inspecting on August 5, all the hives were observed to be badly diseased.

Hive 20 was composed of a new, complete, one-story standard hive previously unused. It contained four new frames with foundation and six badly diseased frames which had received X-ray treatment.[1] The six diseased frames in one package were treated as follows:

"The X-ray equipment used was a deep therapy roentgen ray villard circuit working at a pkv of 180 kilovolts and 6 milliamperes. The frames were exposed as a single unit measuring 46 cm. by 24 cm. by 19 cm. They were exposed four times in all, once on the first day, once on the third day, and twice on the fifth day. The package was exposed for a period of 10 minutes on one side and then turned upside down and exposed for the same period. The distance from the target to the top of the package was 68 cm. and to the bottom it was 85 cm. Measurements with a Victoreen condenser R meter indicated that during each 10-minute period the dose in R units was 520 at the top and 180 at the bottom and hence the dosage during each 20-minute period was 700 R units. The total dosage for the whole period was therefore 2800 R units. All radiation was unfiltered."

A 5-pound package of bees with a laying queen was introduced into this hive on July 15. The colony received two feedings of sugar and water, totaling 7 quarts, on July 16 and July 31. Immediately after introduction, the bees began to remove the scales and debris. Eggs were observed in four frames on July 16. When inspected on August 5, the colony was badly diseased.

Beginning August 6, hives 18 and 19 were treated with sulfaguanidine (1) at the rate of 0.5 gram to one gallon of sugar and water (1 to 1 by volume) through the medium of a *Boardman* feeder. The hives were fed at weekly intervals until October 29, with the exception of the period from September 17 through October 15 when the goldenrod nectar flow occurred. The incidence of disease decreased rapidly and no scales were observed on September 17. However, with the temporary cessation of treatment during the goldenrod flow, it was evident that there had been an

[1] Description of treatment by Richard D. Otis, a medical student and beekeeper, who cooperated in this experiment by making the X-ray treatments with apparatus at his disposal.

increase in the number of disease larvae or the bees had not been as industrious in removing them as a few scales were observed in hive 18 on October 8. On this date only a very few diseased cells remained in each hive. Neither hive produced surplus honey but both colonies were considered to be in good condition.

Hive 12 was secured during the first week of August. This hive was composed of a standard hive body and shallow food chamber. Each chamber contained six badly diseased frames. Hive 12 and hive 20 (the latter originally received X-ray treatment which did not kill the American foul brood disease, as reported earlier in this paper) were treated with sulfapyridine at the rate of 0.5 gram to 1 gallon of sugar and water (mixed 1 to 1 by volume). Each of these hives received 2 gallons of the mixture fed in a *Boardman* feeder. The treatment was made at approximately weekly intervals from August 6 through October, excepting in the period from September 17 until October 15 during a heavy goldenrod nectar flow. Hive 12 was never free of scales during the period of treatment. The scales were harder and not as oily in appearance as those in hives treated with sulfathiazole. All scales in hive 20 had been removed by the introduced package bees before treatment with sulfapyridine. There was a decrease in the number of diseased cells in both hives after the treatment was begun. However, on October 8, when the last observation was made, both hives contained numerous diseased cells and scales. These hives did not produce any surplus honey but appeared to be strong enough to winter successfully.

Hive 13 received in the last week of July, 1946, was composed of a standard hive body and shallow super, not strongly populated with bees, and weak in stores. It was badly infected with American foul brood disease. This hive was given sugar and water (1 to 1 by volume) containing penicillin, buffered with calcium carbonate, at the rate of 50,000 units to one quart of the mixture. One quart of the mixture was fed in a *Boardman* feeder at weekly intervals for a period of 11 weeks. The mixture was shaded from the direct sunlight by placing a lined paper bag over the feeder. The first treatment was made on August 6 and the last on October 29. As the season progressed there was some improvement in the number of bees and evidence of scale removal. The scales in this hive appeared to be hard and dry. When the last observation was made on October 8, diseased cells and scales were more numerous than when the hive was

Table 1.—Statistics of treatments and the results of the analyses[1] for sulfa drugs in the honey of those hives making a surplus in 1946.

Hive No.	Super No.	Drug Used	No. of Treatments	Total Amount of Material[2]	Total Amount of Drug	Sulfa Found in Surplus Honey
				pints	grams	p.p.m.
1	1	Sulfathiazole	2 (spring)	14	.857	0
	2					0
2	1	None	0	0	0	0
	2					0
3	1	None	0[3]	0	0	0
	2					Trace or none
6	1	None	0[3]	0	0	Less than 1
	2					Very faint trace or none
7	1	None	0	0	0	0
8	1	Sulfathiazole	15	55	3.44	8
9	1	Sulfathiazole	13	49	3.06	5
11	1	Sodium Sulfathiazole	8	16	1.00	Less than 1
	2					7
15	1	Sulfathiazole	9	63	7.88[4]	130
	2					15
16	1	Sulfathiazole	9	58	14.50	8

[1] Analyses by the Analytical Chemistry Department of the Conn. Agr. Expt. Sta.
[2] All drugs fed in a sugar water syrup made 1 to 1 by volume.
[3] This hive received treatment in 1945, but not in 1945.
[4] Hive 15 received one gram of drug per gallon of mixture, hive 16 two grams per gallon, while all others received 0.5 gram per gallon.

first secured. Whether this hive will winter successfully is questionable.

Samples of the extractions were taken from each super containing surplus honey and analyzed for sulfa content. The results of the analyses are given in table 1. It will be noted that the table shows that various amounts were obtained in every case the drug was used for treatment when surplus honey was being made. The amounts of the drug found in the supers varied with the duration of the treatment in relation to the storage of the surplus honey. Hive 11 illustrates this fact. Super 1 of this hive was practically filled with capped honey before the treatment began. Treatment started approximately the same time super 2 was placed on the hive. It will be noted that the honey in super 1 contained less than 1 p.p.m. of the drug, while that in super 2 contained 7 p.p.m. Another illustration is found in hive 15, in which the conditions differ. The treatment extended throughout the period required to fill super 1 with surplus honey but discontinued before honey storage ceased in super 2. As shown in the table, it was logical to find a larger quantity of the drug in the honey of super 1.

The table also shows that the largest amount of sulfa, 130 p.p.m. or 0.059 gram per pound, was found in hive 15. This amount of the drug was largely due to the treatment containing 1 gram of sulfathiazole to a gallon of sugar and water, which is twice the usual dosage. The concentration, 0.059 gram per pound of honey, cannot very well be considered excessive, especially since the daily consumption of honey by an individual is probably not more than 4 ounces. Honey consumed at this rate would contain only 0.0147 gram of sulfathiazole. Furthermore, the amount of sulfathiazole ingested while consuming 4 ounces of honey is much less than a medicinal dose prescribed for a child. The initial dose for children is based on 0.15 gram per kilogram of body weight (up to 25 kilograms) followed by a total daily dose of an equal amount administered as prescribed. At this dosage a child weighing 25 pounds or 11.35 kilos would receive a daily dosage of 1.7 grams of sulfathiazole. Assuming that an individual consumes 4 ounces of honey containing 0.0147 gram of sulfathiazole, the amount of the drug ingested would be 115 times less than that prescribed for a 25-pound child and does not appear to be significant.

CONCLUSIONS.—1. That penicillin buffered with calcium carbonate, used at the rate of 50,000 units to one quart of sugar syrup at weekly intervals, is not effective in controlling American foul brood disease in a populated hive.

2. That sulfapyradine used at the rate of 0.5 gram to 1 gallon of sugar syrup did not give any particular promise as a control of the disease in a populated hive.

3. That sulfaguanadine used at the rate of 0.5 gram to 1 gallon of sugar syrup gave results indicative of promise as a control of the disease in a populated hive.

4. That sodium sulfathiazole used at the rate of 0.5 gram to 1 gallon of sugar syrup gave results indicative of promise as a control of the disease in a populated hive.

5. That sulfathiazole used at the rate of 1 and 2 grams to 1 gallon of sugar syrup was not appreciably more efficient in eliminating the disease from the brood than when used at a dosage of 0.5 gram.

6. That when sulfa drugs are fed in a sugar syrup to bees storing surplus honey, they will be deposited in varying amounts in that honey.

7. That furacin used at the rate of 0.5 gram to 1 gallon of sugar syrup did not give any particular promise as a control of the disease in a populated hive.

8. That X-ray treatment at four different periods of 20 minutes each, at 700 R units, did not give any promise as a control of the disease. 12-19-46

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Effect of Carbon Dioxide on Initial Oviposition of Artificially Inseminated and Virgin Queen Bees

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Delayed egg laying has been a great handicap to the completely successful artificial insemination of queen bees. Although Laidlaw (1944) found most queens to start laying within a week after insemination, Watson (1929), Nolan (1932) in his earlier work, and Muzalewskij & Kozlow (1933) experienced an abnormal delay. The writer also had this difficulty. Although he was able to fill the spermatheca with the normal complement of sperm by repeated inseminations, none of the many variations in technique tried lowered the age at initial oviposition to anywhere near that of naturally mated queens. Less than 20 per cent started laying within 30 days after emergence, and as a group they started no earlier than virgin queens. During the delay queens were often balled and mistreated by the worker bees until many of them were killed and those that survived were greatly weakened. It has now been found that proper treatment with carbon dioxide will cause the queens to start egg laying at nearly the normal age, and it is the purpose of this paper to present briefly what has been learned about the use of this gas.

Method of Treatment.—The application of carbon dioxide was very simple. During insemination the gas was made to flow slowly through the queen holder, the queen remaining anesthetized for the duration of the operation, usually about 10 minutes. Separate treatments were made by placing the queen in a deep, wide-mouth container into which a small stream of carbon dioxide was flowing. A lid with an exhaust hole was provided. To reduce the high pressure in the carbon dioxide cylinder, a regulator was attached and adjusted to a delivery pressure of 4 to 5 pounds per square inch. A needle-valve permitted adjustment of the flow of gas to a very fine stream. When only one or two inseminations were made, additional treatments of gas alone were given to make the total number desired. When laying virgin queens were to be produced, only separate treatments were given. The term "treatment," unmodified, will be used to designate an application of carbon dioxide either with or without insemination.

With all the inseminated or treated queens the usual precautions were taken to prevent natural mating, namely, providing the nuclei entrances with zinc queen excluders, and clipping the queens' wings the first or second day after emergence.

Data Obtained Before 1945.—Some data which illustrate the effect of carbon dioxide are brought together in table 1. Although these data were collected over several years, from various experiments not particularly designed to study the effect of carbon dioxide, the method of insemination was practically the same except for differences in number of inseminations and anesthetizations. Queens were established in nuclei as cells on the tenth day after grafting, and since the larvae were young when grafted, emergence may sometimes have been as late as the twelfth day. The ages both at insemination and at initial egg laying were calculated from the day the cells were put out. The age at laying was usually rather roughly estimated from larvae several days old.

Queens in groups 1 and 2 were neither inseminated nor treated with carbon dioxide, and were thus forced to become drone layers. They were clipped and marked and kept in nuclei with zinc excluders over the entrances. Those in group 1 were introduced to nuclei as cells while those in group 2 were kept in constant-temperature cabinets for 16 to 29 days before introduction. In groups 3 and 4 only one insemination was made, but in group 3 sperm was taken from two drones, and therefore a larger amount was given than in group 4 where individual matings were made with sperm from only one drone. In group 5 the two inseminations were 1 to 3 days apart and consisted of injections of 1.5 to 4 mm.[3] of semen, amounts that might be taken from two

[1] In cooperation with Louisiana State University.

Table 1.—Initial-oviposition age of queen bees after various treatments before 1945. Age is given in days after cell introduction.

INSEMINATIONS	GROUP NO.	CO_2 USED	AGE AT INSEMINATION	LAYING QUEENS	AGE AT INITIAL OVIPOSITION	
					Average	Range
None	1 (check)	No	—	12	40	20–62
	2 (check)	No	—	68	40	29–61
One	3	No	2–7	34	47	23–66
	4	Yes	3, 4, 5, or 7	72	36	18–59
Two	5	No	16–28	13	51	32–67
	6	Yes	4, 6, or 5, 7	10	15	11–23
Three	7	Yes	4, 6, 8	10	15	13–18
	8	Yes	5, 7, 9	9	15	13–16
Four	9	Yes	2, 4, 6, 8	6	16	15–16
	10	Yes	3, 5, 7, 9	20	16	14–19

or six drones, respectively. In this group the age range of the second insemination is given. Groups 6 to 10 were of identical stock, and carbon dioxide was used with each insemination. In these groups all queens were either laying or dead 23 days after emergence, while in groups 1 to 5 many died much later.

The following facts are brought out in table 1:

(1) The insemination process has very little, if any, effect on initial oviposition. Queens of groups 3 and 5, inseminated once and twice, respectively, without carbon dioxide, did not lay any sooner than the virgin queens of groups 1 and 2. In other experiments, five to eight inseminations lowered the initial laying age considerably, but not nearly to that of carbon dioxide-treated queens. The high mortality obtained after such numerous operations and the labor involved make such a method entirely unsatisfactory.

(2) Carbon dioxide stimulates egg laying. In group 5 where no carbon dioxide was used the average initial laying age was 51 days, as compared with 15 days in group 6 where carbon dioxide was used. Unfortunately, the inseminations were made much later in group 5 than in group 6. This difference in age makes the groups seem incomparable; nevertheless queens in group 5, inseminated for the second time on the sixteenth day, began laying no earlier than those inseminated later. The average age at initial oviposition of the 127 queens not treated with carbon dioxide (groups 1, 2, 3, and 5) was 43 days, while the corresponding figure for those anesthetized at least twice with carbon dioxide (groups 6 to 10) was 15.4 days after cell introduction.

(3) Two treatments with carbon dioxide are necessary, and additional treatments are apparently superfluous. A single treatment, with insemination, gave only slightly better results (group 4) than insemination without carbon dioxide (group 3). One treatment is therefore not sufficient. That two treatments are necessary is shown more clearly by a comparison of group 4, in which one treatment with insemination resulted in an average initial laying age of 36 days, with group 6, in which two treatments with insemination resulted in an average age of 15 days. Additional treatments, as given in groups 7, 8, 9, and 10, do not lower the average initial oviposition age; however, several treatments at shorter intervals, if completed early enough, might lower the age still further.

DATA OBTAINED IN 1945.—During 1945 additional data on the effect of carbon dioxide on initial oviposition were gathered from a number of small lots of queens. Practically all the inseminated queens were operated on twice, and about half of these were given an additional separate treatment. A few were inseminated three times; and a few, inseminated only once, were also given a separate treatment. Most of the queens treated with carbon dioxide exclusively were given three treatments, but some only two. Treatments, with or without insemination, were 24 or 48 hours apart, and all inseminations were accompanied by anesthetization.

An attempt was made to judge the age more accurately than had been done

Table 2.—Initial-oviposition data on queen bees after second carbon dioxide gas treatment with and without insemination, 1945. Age is given in days after emergence.

Age at Second Treatment	Type of Treatment	Laying Queens	Queens Beginning Oviposition on Indicated Day after Emergence											Average Days Second Treatment to Oviposition
			8th	9th	10th	11th	12th	13th	14th	15th	16th	17th	20th	
3	Inseminated	5	—	—	2	1	1	1	—	—	—	—	—	8.2
4	Inseminated	25	—	3	5	5	4	5	—	—	1	1	1	7.9
5	Inseminated	21	1	—	4	7	6	1	—	1	1	—	—	6.2
	Gas only	10	—	1	4	3	2	—	—	—	—	—	—	
6	Inseminated	2	—	—	1	1	—	—	—	—	—	—	—	4.7
	Gas only	1	—	—	—	1	—	—	—	—	—	—	—	
7	Inseminated	8	—	—	—	2	1	3	—	1	—	1	—	5.7
	Gas only	8	—	—	—	2	4	1	—	1	—	—	—	
8	Inseminated	3	—	—	—	1	—	1	1	—	—	—	—	5.1
	Gas only	7	—	—	—	—	—	5	2	—	—	—	—	
9	Inseminated	3	—	—	—	—	—	2	1	—	—	—	—	5.0
	Gas only	5	—	—	—	—	—	—	3	2	—	—	—	
10	Inseminated	7	—	—	—	—	—	—	—	1	5	1	—	6.0
11	Inseminated	2	—	—	—	—	—	—	1	1	—	—	—	8.5
12	Inseminated	1	—	—	—	—	—	—	1	—	—	—	—	2.0
Total queens treated 3rd to 6th day		64	1	4	16	18	13	7	—	1	2	1	1	11.5[1]
Naturally mated queens		22	4	7	6	4	—	1	—	—	—	—	—	9.6[1]

[1] Average initial-oviposition age.

in previous years. Accordingly queens were allowed to emerge in an incubator and introduced as virgins as soon as possible after emergence. Those that emerged during the night were introduced early the following morning. For the purpose of calculating age, the day of introduction was considered the first day of life. Nuclei were examined daily from the time laying was expected to start, and the time of initial oviposition was determined by subtracting 3 days from the date the first egg was estimated to have hatched. These procedures tend to make the age estimates lower than the methods used in previous years, and account, in part, for the differences found between the ages of comparable groups in tables 1 and 2. A control group of naturally mated queens, reared and mated during excellent weather conditions, was handled and observed similarly except for the omission of insemination and carbon dioxide treatment. Since the conclusion that two treatments are sufficient to stimulate oviposition was borne out in the 1945 data, these data were classified as to age at second treatment, and are presented in table 2.

A comparison in the fifth- to ninth-day groups of the inseminated queens with those given gas reveals only negligible differences, and shows conclusively that carbon dioxide treatments alone are just as effective as when accompanied by insemination.

When the second treatment was given on the third, fourth, fifth, or sixth day, laying started at about the same time, but when the second treatment was given later, the laying age was delayed proportionately. For best results, therefore, at least two treatments must be completed on or before the sixth day after emergence. When the queens treated in this way were compared with the naturally mated queens, the average delay was 1.9 days; however, the majority (59 queens) were delayed only 1.4 days.

The queens receiving the second treatment between the seventh and twelfth days started laying progressively later except in the eleventh- and twelfth-day groups, where the results are probably not representative because of small numbers. The time required for carbon dioxide treatment to stimulate egg production is found in these age groups, because in all of them the initial oviposition age falls distinctly later than in naturally mated queens. The average intervals from the second treatment to initial oviposition were 5.7, 5.1, 5.0, 6.0, 3.5, and 2 days, respectively. For the first four groups these intervals are fairly uniform. The average interval for all the queens in these groups is 5.3 days, which compares

favorably with an average interval of 3.4 days from natural mating to initial oviposition found by Oertel (1940). The difference between these two averages is exactly the same as the delay over naturally mated queens noted in the previous paragraph. Laidlaw (1944) obtained an average interval of 5.14 days from insemination to oviposition.

DISCUSSION.—Although enough is now known about the use of carbon dioxide to make it a valuable aid in artificial insemination, considerable work should be done before it can be used to maximum efficiency. For example, in table 2 it will be noticed that egg laying is extraordinarily delayed in a few queens, one in the fourth-day group having started on the twentieth day. It is also noticeable that these late layers occur most frequently among inseminated queens. Three small groups of inseminated queens were eliminated from the table entirely, because nearly all these queens started laying much later than other queens given the same type of treatment. The cause of these failures is unknown, but since all were inseminated queens it is possible that the carbon dioxide was not flowing fast enough around them during insemination to provide sufficient concentration of gas.

There is still some question as to how close together carbon dioxide treatments can be given. Inseminations have been spaced at least a day apart, preferably 2 days, to allow for the migration of sperm to the spermatheca and for the clearing of dead sperm and mucus from the reproductive tract. A shorter interval might be practical when only carbon dioxide is given, or with a single insemination plus one separate treatment. Of three queens given three 10-minute treatments on the fifth day after emergence, with 30-minute intervals between for complete recovery, one died and the other two were killed when they had not started laying on the twenty-first day. Evidently 30 minutes is not sufficient, and the minimum practical interval lies somewhere between this and 24 hours.

As yet little has been done to determine the optimum length of treatment. A 10-minute period has been used extensively because it takes about this long to inseminate a queen. There is some evidence that 1-minute exposures may be sufficient. At the other extreme, some queens have been exposed for 90 minutes without apparent injury.

The increase in quality and percentage of laying queens obtained with the use of carbon dioxide is mainly brought about by earlier oviposition. Confined, untreated queens will gradually wear themselves out trying to leave the hive to mate during the long period before egg laying starts. They become agitated in the afternoons, and the worker bees, dissatisfied with queens that do not start laying in a reasonable length of time, will mistreat and often kill them. These conditions are eliminated almost entirely by the prompt laying brought about by proper carbon dioxide treatment.

The increase in the percentage of laying queens is not brought out in the tables. Before carbon dioxide was used, the percentage of inseminated queens that started laying was usually less than 60, although occasionally higher percentages were obtained in small groups. The corresponding figure was considerably higher for queens inseminated two or more times, with carbon dioxide as anesthetic. In groups 6 to 10 in table 1 it was 76 per cent, and in the inseminated queens of table 2 it was 73 per cent. In group 4 (table 1), in which carbon dioxide was used only once with one insemination, and egg laying was delayed, this figure was 80 per cent. Although there is less loss from injury with single inseminations, it is thought that the high survival in this group was due, in large part, to the quieting effect of the single carbon dioxide treatment.

How carbon dioxide produces its effect is still a matter of speculation. Its action might very well be one of anesthesia rather than of the gas itself, since there is some evidence that ether has a similar effect. Nolan (1932) inseminated a few queens anesthetized with ether, and the four that produced worker brood began to lay eggs at least 2 days sooner after insemination than seven out of the nine unanesthetized queens in the same category the same year; however, other experimental factors might have brought about these results. A high mortality discouraged further use of this anesthetic. Laidlaw (1944), using ether extensively, reported practically the same results as were obtained by the writer with carbon

dioxide. Of his laying queens, inseminated on the fourth to thirteenth day after emergence, 92 per cent started laying within 7 days after insemination, and, therefore, within 20 days after emergence. Laidlaw inseminated only once, and it is assumed that only one anesthetic treatment was given. A group of queens inseminated once by the writer with one of Laidlaw's syringes, but without his other equipment, and with carbon dioxide instead of ether as anesthetic, laid somewhat sooner than usual, but not so early as those inseminated by Laidlaw. The eight laying queens obtained started laying from 21 to 35 days after cell introduction. This shows that Laidlaw's good results were probably not due entirely to the use of his type of syringe, but possibly to a combination of factors if not to ether alone. The writer used ether on a limited scale in 1939, but discontinued its use when he found it to cause irregular egg laying, especially the deposition of many eggs to a cell, an effect also noted by Laidlaw. Further tests with ether and other anesthetics are in order.

Carbon dioxide is very easy to use, has no ill effect on the operator, and does not leave an odor with the queen that is objectionable to bees. It does not cause the irregular oviposition manifested after anesthetization with ether, and preliminary tests indicate that it has no effect on the number of sperm reaching the spermatheca.

The use of carbon dioxide should be a great stimulus to bee breeding. Not only does it make the artificial insemination process easier and quicker, but its effect on egg laying shortens the generation by at least 15 to 20 days, and increases the number of laying queens by about 50 per cent. With much of the variation due to artificial insemination now eliminated, selection for honey production and other desirable qualities will be more effective. Carbon dioxide apparently has no effect on future performance. In fact, when queens are properly inseminated their performance in full-size colonies can equal that of naturally mated queens. This is clearly brought out in data published by Roberts (1946), in which some groups of queens inseminated with the aid of carbon dioxide performed better than sister queens mated naturally to drones of identical parentage. The method is also valuable in the production of laying virgin queens which are useful in the rearing of drones and in various other breeding activities. Queen breeders might employ this method in their queen-yards during periods when natural drones are scarce.

RECOMMENDATION.—Although there is considerable flexibility in effective carbon dioxide application, until the cause of occasional failures is determined, it is suggested that it be administered as described under "Method of Treatment" and that the individual 10-minute treatments be given as follows; If laying virgin queens are to be produced, a total of three treatments should be given at 24-hour intervals beginning the fourth day after emergence. When queens are to be mated individually, the insemination should be made on the fourth day followed by separate treatments on the fifth and sixth days, or if two inseminations are desired they should be made on the fourth and sixth days with a separate treatment on the seventh day. These schedules can be delayed a few days without great harm except to delay oviposition proportionately, but the intervals should remain the same. Two treatments are usually sufficient, but the third treatment is added to provide a margin of safety.

SUMMARY.—Carbon dioxide gas, properly applied to artificially inseminated or virgin queens, was found to reduce the average age at initial oviposition from more than 40 days to 11.5 days after emergence, which is only 1.9 days more than the average corresponding age of a group of naturally mated queens. This reduction greatly increases both the quality and the quantity of laying queens that can be produced. The data presented in this paper show that the insemination operation has little effect on initial oviposition, that virgin queens will start laying just as quickly as inseminated queens, that two treatments are usually sufficient, and that laying starts in an average of 5.3 days after completion of the second treatment. The method of treatment recommended consists of two 10-minute exposures to concentrated carbon dioxide gas, spaced 24 hours apart, or 48 hours if both are accompanied by insemination, beginning the fourth day after emergence. A third treatment, 24 hours after the second, is recommended to take care of any possible failures.

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Factors Influencing the Effectiveness of Insect Pollinators of Alfalfa in California

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The importance of bees in relation to alfalfa seed production is generally recognized and has recently been discussed by various authors (Tysdal 1940, 1946; Knowles 1943; Linsley 1946; Hare & Vansell 1946; Vansell & Todd 1946; Peck & Bolton 1946, etc.). A previous report has presented the results of a 1945 survey of insect pollinators of alfalfa in California (Linsley 1946). It is the purpose of the present paper to present certain data and general observations upon factors which influence the effectiveness of alfalfa pollinators. These data were obtained during and subsequent to the 1945 survey.

Early in the course of the study it became quite apparent that marked differences existed in various seed-producing areas in California, both with regard to the total numbers of bees present in alfalfa fields and in the total number and per cent of the bees which were tripping and cross-pollinating the flowers. When the 1945 and 1946 population counts for all the fields sampled in each of the four areas studied are summarized (Table 1), it may be seen that there were on the average more than twice as many honey bees in the fields at Hemet as in any of the other three areas, yet the number of pollen-gathering honey bees was not proportionately as great. In addition, the average number of pollen-collecting solitary bees was comparable in the Blythe, Hemet, and Tracy-Patterson (northwestern San Joaquin Valley) areas in 1945 but showed a marked reduction in all areas except in the vicinity of Tracy in 1946. Furthermore, wide ranges in numbers of honey bees and wild bees between individual fields within the various areas were recorded in both the 1945 and 1946 surveys. The following discussion is an attempt to explain at least some of the differences observed.

The methods employed in this study were those described in connection with the report noted above (Linsley 1946). Essentially they involved a combination of direct observation on physiological characteristics of the pollinators, and population studies in a number of fields in various areas. All population samples were taken in 25-sweep counts at stations in the fields, the number depending upon the acreage involved. The majority of the fields sampled were between 10 and 40 acres in extent.

PHYSICAL FACTORS IN THE ENVIRONMENT.—Numerous studies have been made of the influence of temperature, light intensity, cloudiness, moisture, wind, and the like, upon the activities of both honey bees and solitary bees (DeOng 1925; Lundie 1925; Hutson 1926; Phillips 1927, 1930; Woodrow 1932; Brittain 1933; Vansell 1942). Since our observations largely substantiate the conclusions of these authors they will not be reported in detail here. Particular attention was given to those factors which vary with time of day, since they not only have an important influence on the pollination activity of bees but must also be taken into consideration in any sampling method designed to compare one field with another or the same field on various days. Figure 1 presents population trends

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throughout a single day, for both pollen-collecting and nectar-gathering bees in two fields at Patterson, California, as correlated with temperature and relative humidity. Similar data were obtained for three fields (7 all-day counts) in the Hemet area and for two fields at Blythe. Results from all of these studies were similar but varied in detail. The most characteristic feature of the majority of the population curves was a depression in the numbers of both pollen- and nectar-gathering bees in early afternoon followed by an increase later in the afternoon. In general this depression corresponded with the periods of highest temperatures and lowest relative humidities. In one field at Hemet when the temperature at 1 P.M. was 102° F. with a relative humidity of 13 per cent, the count dropped from 136 nectar-gathering bees and 12 pollen-collecting bees (9 A.M. temperature 83° F) to 2 nectar-gathering and no pollen-collecting bees per hundred sweeps. However, at Blythe, where the relative humidities normally remain high throughout the day, a temperature of 106° F. at noon caused a reduction of less than 50 per cent in numbers of nectar-gathering bees and no reduction of pollen-gathering bees compared with counts taken at 10 A.M. with a temperature of 95° F.

Among the factors in the physical environment which are most critical locally for solitary bees are those associated with nesting sites. In general the alfalfa-pollinating solitary bees fall in two classes, those which nest in the ground and those which nest in wood (including hollow stems and twigs). In the case of ground-nesting species most of the cultural practices associated with intensive farming work to their detriment. Cultivation to a depth of 6 inches destroys the nests of nearly all the ground-nesting types except those with deep burrows like the sweat bees (*Halictus*, *Lasioglossum*, *Agapostemon*). Most of the species prefer flat, bare areas of well-drained, more or less sandy soil (in the case of *Nomia*, somewhat alkaline). Also irrigation is detrimental to practically all ground-nesting species, especially during the period of adult activity. Earlier in the season many of the species are resistant to fungi associated with flooding, especially in well-drained soils.

BIOTIC FACTORS IN THE ENVIRONMENT.—Variations in nectar production and in the sugar concentration of the nectar undoubtedly account for some of the marked differences observed in the attractiveness of individual alfalfa fields, and individual plants within a field, to nectar-gathering bees. It is not yet clear, however, to what extent these factors influence the pollen-gathering bees. There is some evidence that sparse, non-succulent growth is more attractive to pollen-collecting honey bees (Vansell & Todd 1946; Tysdal 1946). Both honey bees and solitary bees require nectar for their own physiological processes while collecting pollen. In the case of honey bees, the pollen gatherers can, when necessary, leave the colony with a load of nectar when they start out on a pollen trip. Solitary bees cannot do this and must depend upon nectar which is taken as required during the pollen-collecting trips.[1] It is possible, therefore, that some relation exists between nectar production and the attractiveness of individual fields and plants for pollen-gathering wild bees. The factors which influence nectar production and sugar concentrations include physiological characteristics which are associated with various physical factors in the environment, especially relative humidity and soil moisture (Tysdal 1946), but may also involve certain genetic differences in the plants.

Competing pollen sources may play a significant role in alfalfa pollination, not only in the case of honey bees but also, in varying degree, with defferent species of solitary bees. Hare & Vansell (1946) have given some indication of the importance of competing pollen sources, in the case of honey bees in Utah, based on analyses of pollen pellets. They found greasewood a particularly strong competitor, with 42 per cent of the pollen (by weight) from this source. Vansell & Todd (1946) have also compared the attractiveness of alfalfa, sweet clover, and *Grindelia* to honeybees and certain native wild bees. They report sweet clover particularly attractive to *Nomia*, *Grindelia* to *Megachile*, but both relatively unattractive to honey bees. However, data on the honey bees were apparently limited to nectar-collectors and cannot be inter-

[1] This fact becomes very evident in the case of bees visiting dioecious plants like willow (*Salix*). Robertson (1925) found such bees making 25 pollen visits to willow as against 39 nectar visits to other plants.

Table 1.—Seasonal averages for pollen and nectar-gathering bees per one hundred sweeps in alfalfa seed fields in five California areas, 1945–46.

Area	Year	No. of Fields	Counts	Bees per Hundred Sweeps							
				Honey Bees				Wild Bees			
				Pollen		Nectar		Pollen		Nectar	
				Range	Mean	Range	Mean	Range	Mean	Range	Mean
Blythe	1945	15	29	0–15	5	21–114	44	2–48	10	0–2	1
	1946	7	26	3–37	10	22–99	58	1–7	3	0–1	1
Hemet	1945	7	15	3–18	8	57–152	103	1–23	10	0–3	1
	1946	6	37	6–14	10	158–225	182	0–3	1	0–1	1
Patterson	1945	4	7	0–7	3	38–166	71	3–23	11	1–6	3
	1946	3	4	8–15	11	26–66	48	1–18	9	0–9	3
Tracy[1]	1945	2	7	0–0	0	4–10	7	3–12	7	1–8	4
	1946	2	7	0–0	0	0–7	4	2–19	10	5–18	11
Ryer Island	1945	2	19	2–3	2	42–42	42	18–27	23	3–23	13
	1946	1	2	2–2	2	44–44	44	14–14	14	8–8	8

[1] The low honey bee counts in this area resulted from the removal of most of the commercial apiaries during the alfalfa blooming period in order to avoid arsenical dusts applied to other crops.

preted in the light of pollen competition. In Table 2, data are presented on tamarisk, *Tamarix gallica*, mustard, *Brassica* spp. and sunflower, *Helianthus* spp., as competing pollen sources when growing alongside alfalfa fields in southern California. (In this table the absolute figures obtained by the sweeping method cannot be compared directly from plant species to plant species because of differences in growth form and plant density. In any event, the ratios of pollen- to nectar-gathering bees are such as to indicate the importance of considering competing pollen sources.)

Table 2.—Effect of tamarisk, mustard, and sunflower as competing pollen sources when growing along the edge of blooming alfalfa fields in southern California.

Locality & Date	Pollen Source	Bees per Hundred Sweeps			
		Honey Bees		Wild Bees[1]	
		Pollen-gathering	Nectar-gathering	Pollen-gathering	Nectar-gathering
Field A Blythe July, 1945	Alfalfa	1	23	13	1
	Tamarisk	77	2	5	8
	Sunflower	61	30	42	2
Field B Hemet July, 1945	Alfalfa	1	129	24	2
	Mustard	52	0	18	0
Field C Hemet July, 1946	Alfalfa	20	194	0	0
	Mustard	280	0	3	0
	Sunflower	8	44	10	0

[1] Only wild bees of species known to also pollinate alfalfa were counted.

In the 1946 season large collections of bees were made from a number of cultivated and uncultivated plants adjacent to blooming alfalfa fields in Riverside Co., California. The principal species and species groups of bees have been evaluated as to their relative abundance on each principal plant competitor as compared to their abundance in the adjacent alfalfa fields (Table 3). On the basis of these collections it would appear that among the plants involved sweet clover, *Melilotus alba*, is the most important over-all competitor for alfalfa pollinators, followed in order of importance by mustard, carrot, *Daucus carota*, tamarisk, sunflower, blue curl, *Trichostema* sp., and arroweed, *Pluchea sericea*. These conclusions are based not only on the total numbers of pollen-gathering bees which are diverted from alfalfa but also on the relative efficiency of the bee species involved. The table also suggests that of all the bees important in alfalfa pollination in these areas, the honey bee is most readily diverted from alfalfa by this particular series of competing pollen plants. It should also be pointed out that although several of these plant species are normally good nectar sources for honey bees and wild bees, in the presence of alfalfa they assumed a subordinate role.

Other plant species from which collections were made but which were found to

Table 3.—A rating of some competing pollen plants, when growing near blooming alfalfa fields. Riverside Co., California, 1946.

Bee sp.	Relative Attractiveness as Sources of Nectar and Pollen as Compared to Alfalfa[1]													
	Sweet Clover		Mustard		Sunflower		Tamarisk		Arroweed		Carrots		Blue Curl	
	Pollen	Nectar	Pollen	Nectar	Pollen	Nectar	Pollen	Nectar	Pollen	Nectar	Pollen	Nectar	Pollen	Nectar
Apis mellifera L.	++	+	++	−−	+	+	++	−	+	−	++	+	+	+
Nomia melanderi Ckll.	++	++	−	−−	−−	−					−−	−	−−	−−
Nomia peninsularis Ckll.	++	++			−−	−	−−	−	−−	−	−−	−		
Melissodes timberlakei Ckll.	−	+	−−	−−	−	−	−−	−−	−−	−−	−−	−	−	−
Megachile spp.	−	−−	−	−−	−	−	−−	−−	−−	−−	−−	−	−−	−−
Bombus spp.	−	−	−	−−	−	−					+	+	−	−
Xylocopa varipuncta Patton	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−	−−		
Lasioglossum spp.	−	−	++	−−	−	−	−	−	−−	−−	−−	−−	−−	−−
Halictus spp.	−−	−−	+	−−	+	+	−	−	−−	−−	−	−	−−	−−
Agapostemon spp.	−−	−−	+	−−	+	+	−−	−−	−−	−−	−−	−	−−	−−
Anthidium edwardsii Cresson	−−	−−	−−	−−	−−	−−					−−	−−	++	++
Anthophora spp.	−−	−−	−−	−−	−−	−−	−−	−	−−	−−	−−	−−	++	++

[1] Legend: −− insignificant, − minor, + moderate, ++ great.

be primarily of local importance or only competing for short periods of the day were: Bermuda grass, *Cynodon dactylon*, pigweed, *Chenopodium* sp., plantain, *Plantago* sp., puncture vine, *Tribulus terrestris*, heliotrope, *Heliotropium curassavicum*, milkweed, *Asclepias* spp., Colorado River hemp, *Sesbania macrocarpa*, tarweed, *Hemizonia* sp., and buckwheat, *Eriogonum* sp.

The importance of competing pollen sources suggested the desirability of attempting the elimination of competing plants in the vicinity of alfalfa fields in an attempt to determine whether this would result in an increase in the numbers of pollen-collecting bees in alfalfa. Such an experiment was attempted at Hemet in the 1946 season, with 15 acres of land overgrown with mustard adjacent to a 13 acre alfalfa field. The results of this experiment are presented in table 4. It will be noted from the table that the removal of mustard from 10 acres resulted in a marked increase of bees on the following day in the remaining 5 acres of mustard. It was not until all of the mustard was removed that a marked effect was evident in the alfalfa field. Following the complete removal of the mustard there was a conspicuous increase both in per cent and total of pollen-collecting bees in the alfalfa field although there were other minor scattered patches of

Table 4.—Effect of eliminating 15 acres of mustard as a competing pollen source adjacent to a 13 acre alfalfa field. Hemet, California, 1946.

Date[1]	Bees per Hundred Sweeps					
	Alfalfa			Mustard		
	Pollen-gathering	Nectar-gathering	Per Cent Pollen-gathering	Pollen-gathering	Nectar-gathering	Per Cent Pollen-gathering
July 26	16	141	11.3	302	0	100
August 1	20	194	9.3	280[2]	0	100
August 2	12	136	8.1	472[3]	0	100
August 3	34	192	15.0	—	—	—
August 4	30	216	12.2	—	—	—

[1] All counts between 9:00 and 9:30 A.M.
[2] 10 acres of mustard cut after this count.
[3] Remaining 5 acres of mustard cut after this count.

Table 5.—Relation between populations of lygus bugs and bees in dusted, drifted, and undusted sections of an alfalfa field fifteen days after treatment with 4 per cent DDT-fused sulfur. Ryer Island, California, 1945.

	Bees per Hundred Sweeps					
	Honey Bees		Wild Bees			
Section of Field	Pollen-gathering	Nectar-gathering	Pollen-gathering	Nectar-gathering	Total Bees	Lygus Bugs per Sweep
Untreated Area	0	4	0	0	4	82
Drifted Area	1	54	4	3	62	23
Dusted Area	10	99	16	1	126	11

mustard in the area. It is not known how long this increase may persist but it is suggested that competing pollen sources should probably be abundantly available until alfalfa goes into bloom, then eliminated, provided the apiaries in the area have sufficient pollen in the combs to keep up the strength of the colonies.

Blossom injury by lygus bugs is perhaps one of the most conspicuous of the biotic factors affecting the populations of bees in alfalfa fields. The exact population level at which lygus bugs have a measurable effect upon the bee population has not yet been determined but 1945 data from a single field suggest that in this case it may have been around 10 to 12 lygus bugs per sweep. The effect of large numbers of lygus bugs is clearly evident in table 5, which compares the bee and lygus populations in three parts of a single field on the fifteenth day after dusting the field with 4 per cent DDT-fused sulfur. Although this was an estreme field in the size of the lygus population, it is indicative of differences in bloom resulting from different numbers of lygus bugs.

Parasites, predators, and fungi are also biotic factors influencing the numbers of bees which visit alfalfa fields. Since many of the parasites and predators (nomadine, epeoline and melectine bees, bombyliid and asilid flies, etc.) spend the night in alfalfa fields while the pollinating bees are away, lygus bug control measures applied at this time may have the useful effect of reducing parasites and predators, provided these same measures do not also have a residual effect which reduces the population of bees subsequently visiting the field. Nest-infesting fungi can best be avoided by reducing irrigation to a minimum. When irrigation is required, care should be taken to avoid permitting water to run over roadways and uncultivated areas where solitary bees may be nesting.

PHYSIOLOGICAL CHARACTERISTICS OF POLLINATORS.—A number of physiological characteristics must be considered in evaluating the effectiveness of both individual bees and bee species as alfalfa pollinators. These include (1) the method by which bees orient themselves in relation to a field, (2) their flight behavior within the field, (3) their method of collecting pollen, (4) the rate at which they trip flowers, (5) the amount of time spent in the field, (6) their pollen requirements, (7) the degree of pollen constancy which they exhibit, and (8) their seasonal distribution. When these characteristics are considered in relation to the numbers of bees in a field, rough evaluations of various species may be made.

The flight behavior of the bees involved in alfalfa pollination has considerable bearing on the pollination problem as a whole. Honeybees orienting themselves in a nectar-producing area tend to develop directional flight. Thus Eckert (1933), in a study of the distribution of honey bees from apiaries within a nectar-producing area, found that "bees have a tendency to fly in only one or two major lanes of flight, neglecting similar forage plants in other directions." His experiments also showed that "bees would fly for from 2.75 to 4.6 miles in one direction when located within a nectar-producing area and confine their efforts to working in that direction rather than in nearer fields of seemingly equal attractiveness." This same characteristic was readily observable in alfalfa fields in the 1945 and 1946 seasons. One 40-acre field which had about 30 colonies of bees located within it had one of the lowest honey bee counts of any field sampled, in spite of the fact

Table 6.—Tripping rates of some alfalfa pollinators.

	No. Bees Observed	Flowers Tripped per Minute	
		Range	Mean
Halcitidae			
Agapostemon melliventris Cress.	6	4–12	8
Nomia peninsularis Ckll.	18	4–28	17
Nomia melandri Ckll.	6	4–12	10
Megachilidae			
Anthidium edwardsii Cresson	1	12	12
Diceratosmia subfasciata punctata Michener	4	6–12	10
Megachile brevis Say	15	11–18	16
Megachile gentilis Cress.	1	15	15
Megachile coquilletti Cress.	6	11–20	15
Megachile perihirta Ckll.	7	14–31	22
Apidae			
Melissodes timberlakei Ckll.	13	1–16	8
Anthophora urbana Cress.	2	11–11	11
Xylocopa varipuncta Patton	2	22–24	23
Bombus sonorus Say	1	13	13
Bombus californicus Smith	5	12–21	16
Apis mellifera Linn.	56	1–13	7

Table 7.—Variation in the tripping rates of honeybees during a single day in an alfalfa field. Hemet, California, 1946.

Time of Day	Temperature Range	Number of Bees Observed	Minutes of Observation	Flowers Tripped per Minute
8– 8:30 A.M.	70–76° F.	5	14	7.9
9– 9:30	79–83	5	9	8.5
10–10:30	85–86	5	11	9.2
11–11:30	87–88	5	10	10.5
12–12:30	88–88	5	11	8.4
1– 1:30	89–88	5	9	7.4
2– 2:30[1]	88–87	1	1	1.0
3– 3:30	87–86	5	11	4.5
4– 4:30	86–85	5	11	3.3

[1] An adequate sample could not be taken at this time due to a strong wind which subsided prior to the 3 P.M. count.

that the field was attractive to solitary bees. When, in the latter third of the blooming period, the apiary was moved because of arsenical dusting in the vicinity, no corresponding sudden change in the population curve within the alfalfa field was detectable. The same was true of a 30-acre field which contained about 50 colonies of bees. In the latter case, one of the major lanes of flight was directly down the length of the field, yet the bees were flying beyond the field for their nectar and pollen. In a third field, 5000 honey bees were marked in two colonies placed in the middle of about 45 acres of blooming alfalfa. Although the alfalfa bloom was regularly sampled for bees, no marked individuals were recovered from the 45 acres involved. In at least two cases, however, honeybees placed near isolated fields were observed flying directly to them. No such directional flight was observed in solitary bees, presumably due to the fact that the presence of specific pollen and nectar sources is not communicated from bee to bee, and in general the solitary bees appeared to visit the nearest fields, and the nearest portions of fields, that were in an attractive state. The significance of the directional orientation of honey bees in relation to alfalfa pollination would appear to be that any calculations as to the number of colonies per acre which may be expected to provide adequate coverage by honey bees should be made on an area basis, and that an individual grower who is not completely isolated cannot necessarily count upon the bees in colonies placed directly in his fields.

Another important physiological characteristic which influences the effectiveness of alfalfa pollinators is their method of gathering pollen. Honey bees and bumble bees tend to work more thoroughly over the flowers of a single raceme and the racemes of a single plant, than do the solitary bees. The latter usually move about much more, spending but a short time on individual racemes and upon individual plants. This habit may account for a greater transfer of pollen from plant to plant than is normally accomplished by individual honey bees and bumble bees. In some seed areas of California this factor may be offset by the abundance of small halictine bees which cross-pollinate previously tripped flowers.

The rate at which various species of bees trip flowers, when considered along with the amount of time spent in the field, probably offers one of the best indices of the effectiveness of individual bees as pollinators. A few sample counts of tripping rates are shown in table 6. The tripping rate varies according to the time of day and is probably related to temperature (Table 7). However, the extent to which this and other physical factors actually influence the rate and the rate constancy for various species are matters which require further investigation. In general, the megachiline and nomiine bees have shown consistently higher tripping rates than anthophorine, halictine, and honey bees, although the last appear to spend a greater amount of time in the field.

When pollen requirements of the alfalfa pollinators are considered, the wild bees, individual for individual, are superior,

because every female is a pollen-gathering bee and must store large quantities to rear her young. In the case of honey bees, on the other hand, although pollen is utilized as an essential food item for the brood, it constitutes but a part of the diet. However, honey bees usually store pollen in excess of their needs, although they do not require as much per individual. Fortunately, this is partially compensated for by the large number of individuals in a colony, and at times, a substantial proportion of the field force may be pollen collectors. Thus Vansell (1942), observing the bees returning to colonies at Camino,

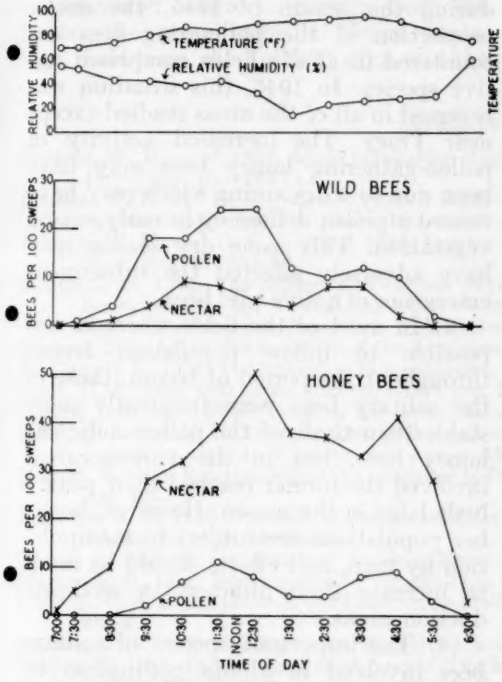

FIG. 1.—Population trends throughout a single day for both pollen- and nectar-collecting honeybees and native wild bees as correlated with temperature and relative humidity. Patterson, California. August, 1946.

California, found an average of 18.5 per cent carrying pollen.

Pollen constancy is useful in evaluating the effectiveness of both species and individuals of pollinating bees. Loew (1884) applied the term heterotropy to the differences which he observed in flower-visiting habits of bees with tongues of about equal length. On this basis he recognized three types, oligotropic, monotropic and polytropic bees, depending upon whether they visited related species of plants, a single species of plant, or unrelated species of plants, respectively. Since these terms were applied to nectar as well as pollen visits, Robertson (1925) proposed the terms oligolectic, monolectic and polylectic for the pollen visits of bees. Since alfalfa is an introduced plant, its pollinators are thus either oligolectic or polylectic, monolectic bees being restricted to endemic plant species. Obviously the most dependable pollinators will be the oligolectic species, since the number of alternative pollen sources to which they may be diverted is limited. Among the wild bees, certain species of *Megachile*, *Melissodes*, *Nomia*, *Anthidium*, and others, appear to be oligolectic, confining their pollen collecting activities largely to legumes. On the other hand, honey bees and certain *Halictus*, *Anthophora*, etc. are polylectic, collecting pollen from almost any available source. However, in spite of these differences which apply at the species level, individual bees show varying amounts of constancy in their pollen-collecting habits. Thus, although certain *Anthophora* species are polylectic, individual bees will collect their pollen largely from one source at a time, provided, of course, that the pollen is available in sufficient quantity. This is evident both from examination of pollen loads from individual bees and from the pollen stored in their cell series. It is well known that the honey bee exhibits the same characteristic. Brittain & Newton (1933, 1934) in an analysis of pollen constancy of various polylectic species visiting apple, found *Halictus* spp. and the honey bee about equally constant, both superior to *Andrena* spp.

Finally, the seasonal distribution of the pollinators in relation to the blooming period of the alfalfa partially determines their effectiveness. Honey bees and some bumble bees are available throughout the blossoming period, and the numbers of the former may be readily increased and manipulated by man, whereas most of the important solitary bees are summer or fall species and have but one generation a year. In general, the solitary bees become more abundant as the season progresses and, in most of the fields under observation, did their most effective work in the latter half of the blooming period. Thus, when honey bees were not abun-

dant, some of the fields which first came into bloom and which bloomed longest showed no significant increases in yields over those which came in later and remained in bloom for shorter periods.

DISCUSSION.—Since the number of pollinating bees in California alfalfa seed fields generally appears to be far less than necessary for maximum seed production, any means for increasing the bees would seem to be well worth while. Honey bees obviously offer the simplest method for increasing numbers since they are under man's control and can be moved from place to place. As indicated previously, however, the mere increase of the honey bee population in an alfalfa field does not necessarily mean a proportionate increase of pollinators, as is evident from a comparison of the figures for the Blythe and Hemet areas (Table 1). Coincident with the movement of bees into the area as alfalfa comes into bloom, there should be attempts made to eliminate sweet clover, mustard, sunflower and other plants which provide competing pollen sources. It is also possible that manipulation of the pollen supply in the colony might have a beneficial effect, although the studies of Todd & Bishop (1941) indicate a tendency in various California localities for bees to rear brood to the limit of the pollen supply. In such cases, pollen manipulation would therefore probably have an adverse effect upon the colony without accomplishing the purpose for which it was designed. Further, it would require the active participation of beekeepers.

The encouragement of native bee populations offers a number of possibilities, although none of them can be expected to yield sudden or immediate results. Since most of the native bees nest near the fields which they visit, it is desirable to grow seed in the immediate area (although not necessarily the same field) year after year. Uncultivated strips should be left near the field to provide sites for nomiine, anthophorine and other ground-nesting bees. Summer irrigation should be avoided whenever possible. Fence posts, logs and dead trees should be left near the fields and drilled full of holes 0.2 to 0.25 inch in diameter and from 4 to 6 inches deep, which may be used by megachilids. These same bees require rose leaves or leaves of similar plants for lining their nest cells, and will fly a quarter of a mile or more for such materials. Rose bushes for this purpose might be planted more extensively around farm houses or along fence rows. Peck & Bolton (1946) have reported preliminary results of attempts to increase artificially populations of *Megachile* in alfalfa seed areas of Saskatchewan and have discussed the possibilities of increasing numbers of *Bombus*.

CONCLUSIONS.—(1) Maximum alfalfa seed production in California appears to be dependent upon the pollinating activities of honey bees and of many wild bees.

(2) In those California areas surveyed during the season of 1945, the major proportion of the pollinating bees encountered in alfalfa fields comprised native species. In 1946, this situation was reversed in all of the areas studied except near Tracy. The increased activity of pollen-gathering honey bees may have been due to a dry spring which may have caused a pollen deficiency in early season vegetation. This same dry season may have adversely affected the subsequent emergence of native wild bees.

(3) In most of the fields where it was possible to follow population trends throughout the period of bloom, those of the solitary bees were frequently more stable than those of the pollen-collecting honey bees, but in the various areas involved the former reached their peak a little later in the season. However, honey bee populations are subject to manipulation by man, and efforts should be made to increase their numbers in seed-production areas.

(4) The important species of solitary bees involved in alfalfa pollination fly more rapidly than the honey bee, trip more flowers per minute, and visit a smaller percentage of the flowers on any one plant, thus apparently accomplishing not only more pollination, but probably also a greater transfer of pollen from plant to plant, per individual bee. The honey bee, on the other hand, appears to spend more time in the field than the wild bees and begins collecting pollen earlier in the morning and continues later in the day.

(5) No noticeable effects upon the honey bee populations of certain fields were evident as a result of the addition or removal of apiaries from these fields.

Apparently honey bees commonly fly long distances in search of pollen and nectar and do not necessarily utilize the most readily available source. Thus, if honey bees are to be used to increase alfalfa pollination, calculations should be based on an area as a whole, not on individual fields.

(6) The encouragement of wild bee populations does not appear to be hopeless and a number of possibilities should be tried experimentally. Factors which favor the increase of wild bees would appear to include the production of seed in any particular vicinity year after year; a minimum of summer irrigation; allowing uncultivated strips to remain near the fields; the preparation of fence posts, logs, dead trees, etc. for nest sites, and the planting of rose bushes and certain other plants in the vicinity to provide suitable nest materials for megachilids.

(7) Elimination of sweet clover, mustard, sunflower and various other plants which blossom during the period when alfalfa is in bloom, should increase the number of pollinating honey bees in alfalfa as well as that of certain of the species of wild bees. Wherever possible, competition with other seed crops, especially carrots, should be avoided.

(8) The abundance and effectiveness of pollinating bees can be increased by lygus bug control, thus reducing blossom injury by these bugs, provided the measures employed do not themselves have a detrimental effect upon the bees and their activities.

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The Effects of DDT and Certain Other Insecticides on Alfalfa Pollinators

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In connection with the use of dichlorodiphenyl-trichloroethane and other insecticides for the control of lygus bugs on alfalfa seed crops it is obviously important to determine the effects of these materials on pollinating insects. It has been established that most varieties of alfalfa must be tripped and cross-pollinated by bees in order to assure a satisfactory seed set. Also, alfalfa provides one of the most important sources of nectar for commercial beekeepers, particularly during the summer months in California. For these reasons field studies were undertaken in connection with the extensive control experiments reported by Smith & Michelbacher (1946) in an attempt to determine the effects of applications of insecticides upon field populations of bees which visit alfalfa. Since the selection of the fields, the design of the field tests, and the methods of application of the insecticides in the 1945 season have been described by them, they need not be repeated here, as essentially the same procedure was followed in 1946.

Eckert (1945) has reported the results of tests as to the effect of DDT on honey bees when (1) a solution was sprayed on cages in which the bees were later confined, (2) when various concentrations of dusts were sprinkled on the bees in cages and in their hives, and (3) when DDT was mixed with queen-cage candy, pollen, and sugar syrup. Shaw (1946) has recorded tests with solitary bees and bumble bees which were confined in cages and dusted lightly with 5 per cent DDT. These studies indicate that when various concentrations of DDT dusts are applied directly to bees, some or all of the bees may be killed. Wolfenbarger (1944) and Kulash (1945) have utilized DDT for the destruction of out of place honey bee colonies.

Methods.—Population trends of bees during the blooming period of the fields were followed by means of the sweeping method reported by Linsley (1946a). All population samples were taken in 25-sweep counts, with the number of stations depending upon the acreage involved. The majority of the fields sampled were between 10 and 40 acres in area. During the 1945 season 30 fields were sampled and in 1946, there were 27. The fields were selected from four of the major seed-producing areas of California (Palo Verde Valley, Hemet area, northwestern San Joaquin Valley, and southern Sacramento Valley), and during the periods in which the counts were made the number of colonies of honey bees in each area was relatively static.

In the 1946 season, cage tests were also undertaken although it was recognized that such tests might not be comparable to those made in field conditions. In these tests random samples of 20 bees each were collected from the both the dusted and the undusted sections of the experimental fields. Each bee was collected individually in a clean test tube and care was taken to avoid contamination of the tubes by the insecticide. In order to standardize the tests, in so far as possible, only young bees were taken and they were collected just as they left the flower. After the bee was collected, the tube was progressively darkened permitting the insect to move into the cage as a result of phototropic response.

Each cage[2] used in these experiments consisted of a wooden frame with inside measurements of five eights inch by 3 by 4 inches, with a bottom and a sliding top of eighth-inch hardware cloth or galvanized window screen. A half-inch lateral entrance hole permitted the introduction of the bees. Each cage contained two small beeswax cups of nutrient solution (cane sugar in water, 1 to 1 by volume).

In the early stages of the study there was some doubt in the minds of the investigators as to whether the handling of a group of bees in a single cage might not permit contamination or induce vio-

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[2] The cages were designed by J. E. Eckert and were similar to those used in previous studies (Eckert 1945).

Table 1.—Honey bee population trends in alfalfa seed fields treated with 5 per cent DDT in talc applied by airplane.

Date and Amount Applied per Acre	Locality	Average Number of Bees per Hundred Sweeps					
		Pre-treatment Counts			Post-treatment Counts		
		Date	DDT	Check	Date	DDT	Check
June 17, 1945 30 lbs.	Hemet	6/16	109	129	6/17	78	141
					6/18	102	140
					6/19	119	132
July 3, 1946 38 lbs.	Hemet	7/2	208	176	7/3	174	220
					7/5	196	180
					7/6	230	176
					7/8	184	180
					7/14	125	110
July 4, 1946 32 lbs.	Hemet	7/3	165	172	7/4	108	204
					7/5	145	290
					7/7	232	324
					7/9	222	220
					7/16	214	142
July 6, 1946 33 lbs.	Hemet	7/3	102	124	7/6	74	158
					7/7	174	264
					7/9	156	182
					7/11	123	162
					7/20	223	190
June 9, 1945 30 lbs.	Blythe	6/8	76	82	6/9	32	104
					6/10	107	158
					6/11	164	135
					6/12	130	120
June 19, 1946	Blythe	6/18	102	123	6/19	34	124
					6/20	72	123
					6/21	85	110
					6/22	96	95
					6/26	102	84

lent individual reaction. For this reason the cage test bees were checked against an equal number of individual specimens confined in test tubes. The mortality rates were found to be entirely consistent in the two methods. In both cases the bees remained relatively quiet under the confined conditions and readily fed on the sugar syrup provided.

During the period of collection (15 to 20 minutes) the cages were kept in the shade and as soon as the required number of bees were obtained each cage was placed in a large cardboard carton covered with wet sheets. These cartons were stored indoors and temperature readings taken each time the sample was checked. Temperatures in the cartons ranged from 17° to 32° C., with the majority of readings between 21° and 27° C.

POPULATION TRENDS IN DUSTED FIELDS.—When data from all the fields dusted with 5 per cent DDT were analyzed, they exhibited a characteristic pattern of population trend. In all cases honey bee population samples taken by the sweep count method were smaller on the day in which the dust had been applied than counts taken in the same section, at the same hour, on the previous day. Coincident with this reduction the untreated sections of the field usually showed an increase over counts taken at the same time on the previous day. The counts taken on subsequent days demonstrated a gradual buildup of the population in the dusted area over a 3 or 4 day period. In most instances the population in the dusted section reached a peak higher than it had been the day before dusting or that in the check area.[3] In general the depression in the population on the day in which the dust was applied

[3] This effect becomes most conspicuous where populations of lygus bugs were high prior to dusting, and has been reported previously by Vansell and Todd (1946) and Linsley (1946b).

Table 2.—Population trends of honey bees and native wild bees in an alfalfa seed field on Ryer Island, Calif., treated on July 16 and again on August 9, 1945 with 4 per cent DDT-fused sulphur applied by ground machine at approximately 30 lbs./acre.

Average Number of Bees per Hundred Sweeps							
First Dusting Counts				Second Dusting Counts			
Date	DDT-fused Sulphur	Drifted Area[1]	Untreated Area[2]	Date	DDT-fused Sulphur	Drifted Area[1]	Untreated Area[2]
			Honey Bees				
7/25	71	57	49	8/11	27	46	0
8/1	109	56	4	8/16	48	32	0
8/6	96	46	0	8/21	78	24	0
8/9	87	42	0	8/25	68	26	0
			Wild Bees				
7/25	12	14	1	8/11	6	4	0
8/1	17	6	0	8/16	5	6	0
8/6	14	5	0	8/21	24	5	0
8/9	13	5	0	8/25	18	7	0

[1] Drifted area almost identical in both treatments.
[2] Low population in untreated area due to uncontrolled blossom injury by lygus bugs.

was not less than 30 per cent, nor greater than 50 per cent, when the counts were taken at about the same hour each day and when climatic conditions were similar. For examples of honey bee population trends in dusted fields see table 1. Native wild bee populations did not, however, exhibit the same depressions that were evident in the case of honey bees. However, in the 1946 experimental fields the wild bee populations were too low to permit satisfactory conclusions. In one field at Hemet, bumble bees were more abundant on the day of dusting than they had been on the previous day. Further study will be required to determine whether or not wild bees and honey bees react differently to DDT dusts.

Similar honey bee population curves were obtained when fields were dusted with 3 per cent DDT at both 20 and 30 lbs. per acre. In these experiments evidence was not, however, clear as to what extent the depressions varied with materials or rates of application. There was some suggestion that the population depressions were less pronounced in lighter applications of 5 per cent DDT at 20 lbs. per acre and in applications of 3 per cent DDT at 30 lbs. per acre in fields where these rates of application were compared directly with 5 per cent DDT at 30 lbs. per acre.

Honey bee population trends in a field to which had been applied a dust containing 4 per cent DDT fused with 85 per cent sulphur were similar to those described above but the recovery period was greater, involving a week or 10 days (Table 2). In addition there was visible injury to the bloom as a result of application of this material. When this dust was applied while the bees were in the field, population curves for native bees and honey bees were similar.

In one field in which 5 per cent DDT with 50 per cent sulphur was compared with 5 per cent DDT in talc, both applied at approximately 30 lbs. to the acre, no difference in population curves was evident. In the application involving sulfur, a slight burning of the edges of the petals was visible for several days.

In one experiment a comparison was made of the effects of dusts containing 3 per cent *Velsicol 1068*, 1 per cent gamma isomer of hexochlorocyclohexane, 5 per cent dimethoxy-diphenyl-trichloroethane and 50 per cent sulphur in inert carrier, and 5 per cent DDT all applied at about 30 lbs. per acre on a 34 acre field. In this case the honey bee population curve showed the least reduction with 5 per cent DDT. In another case where 5 per cent DDT was compared with 5 per cent dimethoxy-diphenyl-trichloroethane in inert carriers, the greatest reduction was in the DDT section of the field.

Visible Effects of Insecticides on Behavior of Field Bees.—Honey bees entering a field on a morning when DDT has been applied do not immediately alight on the blossoms in the usual manner, but approach a variable number of

racemes before taking nectar. This behavior pattern, which is similar to that which occurs when nectar is scarce, may be observed for several hours in the morning. In addition about 5 per cent or less of the field population on the morning of dusting would be found resting on the alfalfa plants, either motionless or cleaning their tarsi and mouthparts.[1] Occasionally, particularly when disturbed these bees would fall to the ground. After a few seconds of buzzing on the ground they would fly off. On one occasion a bee was seen to fall from a flight lane into the road but after a few minutes on the ground it was able to fly away. During the collection of honey bees for cage tests in the first few hours after dusting, approximately 15 to 20 per cent of the bees, taken while flying off of the flowers, either failed to show a clear-cut positive phototropic reaction in moving from the test tube to the cage or they showed partial paralysis of the legs while walking in the test tubes. This reaction was much less noticeable later in the day and was only occasionally detectable on the following day. However, in spite of all such aberrant behavior of bees in DDT-dusted fields no unusual numbers of dead bees were noted in the dusted fields even in row plantings where dead bees may be readily observed. Observations on native wild bees were inadequate but no abnormalities in behavior were noted during these studies.

In the 1945 season, sabadilla was applied to a field at Blythe at about 30 lbs. per acre. Within a few hours after the bees entered the field practically all of the bees were exhibiting abnormalities of behavior. Many were hanging on the plants cleaning themselves and a large number were buzzing around on the ground about the base of the plants and apparently dying. Similar observations were made in another application of this material. The visible effect upon bees in these two applications was greater than with any of the other materials studied.

RESULTS OF CAGE TESTS.—Cage tests were made with honey bees collected from fields dusted with 5 per cent DDT at rates of application varying from 20 to 43 lbs. per acre (Table 3). Where the rate of application was approximately 20 pounds per acre, from 60 to 100 per cent of the bees in samples collected on the day of dusting died within 24 hours. In a sample taken from one of these fields the afternoon of the day following dusting, only 10 per cent of the bees were dead in 24 hours.

Where the rate of application was approximately 30 lbs. per acre, from 80 to 100 per cent of the bees collected on the morning of dusting were dead in 24 hours. In a sample taken on the morning of the second day, 15 per cent were dead in 24 hours, while of a sample taken in the afternoon, 25 per cent died.

Where the rate of application was about 40 lbs. per acre, only 50 to 67 per cent of the bees were dead in 24 hours. Yet samples taken from one of these fields on the morning and afternoon of the day following dusting, showed 35 and 30 per cent mortality, respectively, in 24 hours.

In general it was observed that honey bee samples collected on the morning of dusting showed a smaller per cent initial mortality (at 6 hours) than was true of samples taken later in the day. However, the final mortality (at 24 hours) was not strikingly different. There was no further

Table 3.—Results of cage tests with honey bees collected from alfalfa fields treated by airplane with 5 per cent DDT in talc.

Pounds per Acre	Locality	Number of Bees	Hours after 7 A.M. Bees Collected[2]	Per Cent Bees Dead in Indicated Hours[1]		
				6	12	24
20	Hemet	20	3	25	75	100
21	Hemet	20	4	35	70	85
21	Hemet	20	4.5	10	40	75
21	Hemet	20	5	10	35	60
20	Hemet	20	7.5	30	80	90
20	Hemet	20	33.5	0	10	10
31	Hemet	20	3.5	25	70	100
31	Hemet	20	4	20	70	80
29	Hemet	20	4.5	5	75	90
32	Hemet	20	6	80	85	90
32	Hemet	20	6.5	50	75	100
32	Hemet	20	6.5	65	75	90
31	Hemet	20	7	90	95	100
32	Hemet	30	7.5	83	92	92
31	Hemet	20	8	80	95	100
31	Hemet	20	27.5	0	10	15
31	Hemet	20	33	0	15	25
40	Blythe	30	3	3	30	56
43	Blythe	30	3	7	33	50
43	Blythe	20	5	5	45	70
41	Blythe	30	5.5	16	53	60
40	Blythe	30	6.5	33	53	67
41	Blythe	20	27	10	25	35
41	Blythe	20	51	15	30	30

[1] Data from bees collected from undusted check areas showed a mortality in 24 hours of from 0 to 5 per cent.

[2] Because the time of application varied from 4:30 A.M. to 7 A.M., all counts were measured from 7 A.M., approximately when the bees first came into the fields.

[1] When 10 such bees were caged 4 hours after dusting, 50 per cent died in 3 hours, 90 per cent in 24 hours.

mortality after 24 hours when cages were kept for 48 to 72 hours. In these same periods of time the rate of mortality in caged bees from untreated areas was not more than 5 per cent (1 bee in 20). Native wild bees were extremely difficult to capture without contamination and for this reason experiments comparable to the above were impossible. In one case, a few specimens of *Nomia peninsularis* collected from the dusted section of a field and held in cages failed to die in 24 hours.

DISCUSSION.—A striking characteristic of blooming alfalfa fields dusted with DDT and certain other insecticides is the distinct depression in the population of bees which becomes evident shortly after dusting. Two possible explanations for this depression are suggested. The most obvious conclusion would be that this depression reflects bee mortality. In favor of this argument are: (1) the presence of "sick" bees hanging onto the foliage, (2) evidence of paralysis in bees collected for cage studies, and (3) the high percentage of mortality in caged bees collected from dusted fields, Although these facts do not indicate its extent, they strongly suggest that some field mortality occurs. Furthermore, some beekeepers claim to have sustained serious losses of field bees following applications of DDT. Against the argument that the depression is wholly explainable on the basis of mortality are: (1) the very rapid build-up of field populations of bees after dusting, even where a high percentage of the blooming alfalfa fields in any one area are dusted more or less simultaneously, (2) the reduction of the field population rarely surpassed 50 per cent of what it was on the day before dusting, (3) the absence of dead bees in dusted fields or at apiaries, and (4) the fact that many beekeepers have reported no evidence of depletion of their field force following applications of DDT. It should be pointed out, however, that the absence of dead bees in the fields and at apiaries may merely indicate that bees affected with DDT leave the field and die without returning to their hives.

If the population depressions which invariably follow dusting are not a reflection of large scale bee mortality, some other explanation must be offered. It has been suggested by some workers that the dust acts as a repellent to the bees and keeps them from the field until such time as new flowers open to make the bloom once again attractive. Two further points argue in favor of this explanation, (1) there is almost invariably a rise in the population in undusted areas coincident with the decrease in dusted sections, and (2) bees, upon entering a newly dusted field, fail to light normally on the dusted flowers but fly from raceme to raceme for some time. Such an explanation, however, would have to be based either on the assumption that the bees which die under the confined conditions of the cage tests would otherwise have left the field and have recovered from a sublethal dose of DDT, or one that most of the bees which would have normally entered the field were repelled before doing so.

CONCLUSIONS.—On the basis of field observations during the 1945 and 1946 seasons, the following conclusions may be drawn as to the effect of DDT and certain other insecticides on alfalfa-pollinating bees.

1) Following dusting of alfalfa in bloom with DDT and certain other insecticides there is an almost immediate decrease in the number of bees in comparison with those which were present at the same time on the previous day. This depression is followed by a build-up of the population which usually requires 3 or 4 days. In the case of 4 per cent DDT-fused sulphur this recovery period appears to require a longer period of time.

2) Coincident with the depression of the population in fields dusted with DDT there is usually an increase in adjacent undusted sections.

3) When honey bees are collected and caged from fields recently dusted with DDT, a large percentage of them die within 24 hours.

4) Large scale bee mortality under field conditions has not yet been demonstrated experimentally.

5) In spite of the suggestiveness of cage tests, the possibility still remains that depressions in bee populations following application of certain insecticidal dusts may be largely or partially the result of some sort of repellent action.

6) More work will be required before it can be stated whether or not DDT and certain other insecticides applied to alfalfa in bloom will kill a sufficient number of the native wild bees and honey bees to

influence adversely tripping and cross-pollination, or to affect the beekeeper economically. In the meantime, it is suggested that where DDT is to be used for lygus bug control, it be applied as early in the growth of the plant as the lygus population warrants and that a second dusting be applied only when absolutely necessary.—1-14-47.

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Increasing Red Clover Yields by Treatment with DDT or Hexachlorocyclohexane

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It has long been recognized that the various forage crops are hosts for large numbers of insects. The probable amount of injury they cause has, however, been a matter of debate among entomologists and agronomists. The study reported here was a preliminary attempt to determine the extent of insect injury to red clover in New York. The possible hazards due to insecticide residues remaining on the plants was an additional consideration.

Three 40 by 40 foot replicates of six treatments and a check, arranged in a randomized block, were laid out on a thick, even stand of red clover and timothy near Skaneateles, New York. The meadow was in its first crop year. The seeding mixture contained 6 quarts of clover and 5 of timothy. The six treatments were as follows:

1. DDT dust, 1 per cent, 50 pounds per acre, applied May 13, May 20, May 27, and June 3.
2. DDT dust, 2 per cent, 50 pounds per acre, applied May 13, and May 29.
3. DDT dust, 3 per cent, 50 pounds per acre, applied May 13, and June 3.
4. Hexachlorocyclohexane, 1 per cent mixed isomers, .133 per cent gamma isomer, 50 pounds per acre, applied May 13, May 20, May 29, and June 3.
5. Hexachlorocyclohexane, 2 per cent mixed isomers, .266 per cent gamma isomer, 50 pounds per acre, applied May 13, and May 29.
6. Hexachlorocyclohexane, 3 per cent mixed isomers, .399 per cent gamma isomer, 50 pounds per acre, applied May 13, and June 3.
7. Check.

The crop was cut on July 6. The interval between last treatment and cutting therefore was 33 days for all 1 and 3 per cent materials, and 38 days for both 2 per cent materials.

In cutting the hay for yields a 3 foot swath around the block and along all plot boundaries was removed with a scythe after which the plots were cut with a power mower. All cuts with the power mower were taken in one direction. A crew of five men followed the mower and immediately stacked the green hay to reduce moisture loss to a minimum during the short period between cutting and weighing. Green weights were taken in the same order that the plots were cut and stacked. After weighing, the green hay was redistributed over the plots and cured for two days under ideal weather conditions. The cured hay was weighed, baled, graded, and stored in a manner to insure adequate ventilation.

After analysis for residue (see Table 1), hay from the three DDT plots was mixed

[1] The authors are indebted to Dr. J. K. Loosli, Professor of Animal Nutrition, Cornell University, who furnished experimental animals, and animal quarters, and supervised the feeding experiment.

Table 1.—DDT residue in clover hay, Ithaca, N. Y.—1946.

Amount DDT Applied (All at 50 Lbs. per Acre)	Interval Between Last Dusting and Cutting	P.P.M. of DDT
1%—4 applications	33 days	12
	33 days	13
	33 days	10
2%—2 applications	33 days	6
	33 days	6
	33 days	6
3%—2 applications	38 days	17
	38 days	13
	38 days	13

Table 2.—Increases in yields of red clover after treatment with DDT or hexachlorocyclohexane—Skaneateles, N. Y.—1946.

Treatment	Green Wt. (Totals for 3 Replicates)	Dry Wt. (Totals for 3 Replicates)	Per Cent of Increase Over Check	
			Green Wt.	Dry Wt.
Benzene hexachloride—1%	1271	537	22.0	10.7
DDT—1%	1205	532	15.7	9.7
Benzene Hexachloride—2%	1225	538	17.7	10.9
DDT—2%	1212	527	16.4	8.6
Benzene hexachloride—3%	1146	520	10.0	7.2
DDT—3%	1195	516	14.8	6.4
Checks	1041	485	—	—

and fed to a diary cow daily for a two-month period. DDT analyses on milk, urine, and faeces from the cow were made.

As shown in table 2, the greatest increases in yield of clover hay were obtained from the plots dusted with one or two per cent material. Differences between treatments other than the check probably are not significant, but increases over the check plots are significant.

Shortly before cutting time the much better condition of the treated plots was shown by their greener color, greater percentage of blooming, and small amount of timothy.

Figures on the numbers of various insects present in the plots were obtained from sweepings, cuttings of roots, and examinations of clover blossoms. The principal species present in the area and believed to be responsible for the greater part of the injury observed were a clover weevil, *Hypera meles;* the clover head weevil, *Tychius griseus;* the tarnished plant bug, *Lygus oblineatus;* the clover root curculio, *Sitona hispidula;* the meadow spittlebug, *Philaenus leucophthalmus;* the potato leafhopper, *Empoasca fabae;* the clover root borer, *Hylastinus obscurus;* and several species of aphids. Reduction in infestation was most apparent in the cases of the weevil *Hypera meles,*[1] and the meadow spittlebug. Aphids were significantly reduced soon after each treatment but built up in numbers rapidly afterward. Infestations of the tarnished plant bug and potato leafhopper were too small to yield significant figures. Table 3 shows the reductions of *Hypera meles* and spittle insects obtained as shown by diagonal sweepings of the plots, or head examinations. It was soon discovered that sweeping gives an inaccurate estimate of the numbers of *Hypera meles* present because only the adults are caught. In another block of plots head examinations instead of sweepings were used to determine the control of larval stages of this insect and much more significant reductions were shown (Table 4). Control of the clover root borer was significant but not adequate when four applications of either 1 per cent DDT or 1 per cent hexachlorocyclohexane were used. Eighteen per cent of the plants examined from the 1 per cent hexachlorohexane plot were infested, 30 per cent from the 1 per cent DDT and 45 per cent from the check.

Hay from the three DDT treated plots

[1] In the official list of common names, *Tychius griseus* is listed as the clover head weevil. It probably should be called the clover seed weevil since it infests only the ovules. *Hypera meles,* which is not mentioned in the list, infests the entire head, living among the florets. It probably should be called the clover head weevil.

Table 3.—Control of *Hypera meles* and *Philaenus leucophalmus* with DDT and hexachlorocyclohexane—Skaneateles, N. Y.—1946.

Species	DDT			Hexachlorocyclohexane			Check
	1%	2%	3%	1%	2%	3%	
Hypera meles—adults from sweeping	19	52	101	48	64	96	121
Hypera meles larvae found in 510 heads	117	222	229	93	180	224	414
Philaenus leucophthalmus adults from sweeping	398	508	634	62	84	102	1819

Table 4.—Control of *Hypera meles* with DDT and hexachlorocyclohexane as shown by examination of 200 heads—Minetto, N. Y.—1946.

Treatment	Heads Infested with Larvae			
	June 7	June 14	June 22	Totals
hexachlorocyclohexane spray—1% 3 applications	18	1	0	19
hexachlorocyclohexane 5% dust 4 applications	26	4	0	30
DDT 5% dust 4 applications	12	8	2	22
Check	140	141	120	401

was mixed and fed to a dairy cow daily during the period from August 8 to October 8. No symptoms of DDT poisoning were observed in the cow. According to the hay analyses the maximum daily dose the animal could have obtained was 121 milligrams. Orr & Mott have shown that about 500 times this dose must be fed daily for about 2 weeks to produce even minor symptoms. The first milk analysis was made on September 3, which was 26 days after feeding began, and 4 days after the cow freshened. At this time, 0.22 ppm of DDT was found. Seven subsequent analyses made at 3 to 7 day intervals from September 7 to October 2 showed a fairly continuous increase in the

Table 5.—DDT content of milk from a cow fed for 2 months on clover hay containing an average of 10.77 ppm of DDT.

Feeding began—August 8
Feeding ended—October 8
Cow Freshened—August 31

Sept. 3—.22 p.p.m.	Sept. 21—.58 p.p.m.
7—.40	25—.92
14—.87	28—.83
18—.82	Oct. 2—.62

DDT content of the milk, the maximum of 0.92 ppm occurring on September 25. Additional analysis are in progress. While 0.92 ppm is a relatively small DDT content, it should be remembered that butter made from this milk might contain nearly 30 times this figure, or about 26 ppm of DDT. No DDT was found in a blood sample taken on August 8, or in urine samples taken on August 12 and August 22. Fecal analyses made on August 12 and August 30 were negative, but one made on September 20 showed the presence of 0.04 ppm of DDT.

Hay from the plots treated with hexachlorocyclohexane was fed to a second cow without observable effect on her health. No odor was detected in the milk from this animal.—1-21-47.

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New Insecticides for Boll Weevil, Bollworm and Aphid Control[1,2]

J. C. Gaines and H. A. Dean,[3] *Texas A & M College, College Station*

Investigations have been continued in an effort to find an effective insecticide for the control of the bollworm, *Heliothis armigera* (Hbn.), boll weevil, *Anthonomis grandis* Boh. and cotton aphid, *Aphis gossypii* Glov. Calcium arsenate has proven to be economical against the weevil but in some years aphid increases occur after a large number of applications and may cause considerable injury. This insecticide, applied in heavy doses, has also proven to be profitable when used against the bollworm, but it is not as toxic as an insecticide should be to give full protection to the crop under the conditions of a severe infestation. Planters have experienced some difficulty in applying heavy doses of calcium arsenate at the correct time to prevent a loss. The high rates per application tend to produce aphid increases, which in turn may reduce the benefits derived from controlling the worms.

Work has been conducted here over a

[1] Technical contribution No. 997 Texas Agricultural Experiment Station in cooperation with the Bureau of Entomology and Plant Quarantine, United States Department of Agriculture.

[2] Cotton States Branch program paper.

[3] R. Wipprecht, W. J. Magee, F. A. Gibson, R. L. Hauk, G. L. Atmar and D. R. Tumlinson assisted in taking the field notes.

period of years, using the promising insecticides. Reports of the results of these tests have been published in the JOURNAL OF ECONOMIC ENTOMOLOGY. Cryolite has proven effective against the bollworm, but yields have been reduced when weevils occurred in injurious numbers. Apparently the toxicity of cryolite was reduced when alternate applications of cryolite and calcium arsenate were used. Lead arsenate is more effective against weevils than cryolite, more effective against bollworms than calcium arsenate, and has given good results alone, or when used alternately with calcium arsenate for weevil and bollworm control; but aphid increases may occur which reduce the yield.

The tests herein reported, conducted in the Brazos River bottoms near College Station, Texas, during 1946, were designed to compare the newer insecticides, benzene hexachloride and DDT, with calcium arsenate for the control of weevils, bollworms and aphids. Cage tests (Ivy & Ewing 1946) indicated that DDT was more toxic than either calcium arsenate or benzene hexachloride when used against the bollworm, but that benzene hexachloride in certain concentrations was perhaps more toxic than either of the other materials against the weevil. It was deemed advisable to test the two insecticides alone and in combination for complete control of cotton pests.

FIELD PLATS AND TREATMENTS.[1]—In experiment No. 1, the plats were arranged in randomized blocks and each treatment was replicated six times in early planted D and PL variety of cotton. The dusting area of each plat was 0.1 acre (12 rows wide) and the picking area after the buffers were eliminated was 0.043 acre (6 rows wide) in size. The following insecticides were used: commercial calcium arsenate; DDT-pyrophyllite mixture, containing 5 per cent DDT; benzene hexachloride-fullers earth mixture containing 5.75 per cent gamma isomer; and DDT-benzene hexachloride-pyrophyllite mixture containing 5 per cent DDT and 2.88 per cent gamma isomer. Seven effective applications of all insecticides were made at approximately 5-day intervals. Three of the applications were made early in the season, before the bollworm moths transferred to cotton, at an average rate of 6 pounds per acre; the later applications, made after the bollworm began to cause injury, were applied at an average rate of 11 pounds per acre.

In experiment No. 2 the plats were also arranged in randomized blocks and each treatment was replicated four times in early planted Stoneville (2-B) variety of cotton. The dusting area of each plat was 0.083 acre (12 rows wide) and the picking area after the buffers were eliminated was 0.04 acre (6 rows wide) in size. The insecticides used in this experiment were the same as those used in experiment No. 1 except that the diluent used with DDT was sulphur instead of pyrophyllite. Six effective applications of all insecticides were made at 5-day intervals at an average rate of 12 pounds per acre after the bollworm moths transferred to the cotton.

In experiment No. 3 the plats were also arranged in randomized blocks and each treatment was replicated four times in early planted D and PL variety of cotton. The dusting area of each plat was 0.083 acre (12 rows wide) and the picking area after the buffers were eliminated was 0.033 acre (6 rows wide) in size. The insecticides used in this experiment were as follows: commercial calcium arsenate, commercial calcium arsenate plus 1 per cent nicotine, and benzene hexachloride-pyrophyllite mixtures containing 4.31, 2.88 and 1.44 per cent gamma isomer. Eight effective applications of all insecticides were made at approximately 5-day intervals. Three applications were made from June 19 to July 1 at an average rate of 7 pounds per acre before bollworm moths transferred to cotton. The other applications were made from July 12 to August 6 at an average rate of from 11 to 12 pounds per acre.

In experiment No. 4, the four varieties of cotton: Lankart, Rogers Acala, Shafter Acala and Stoneville (4-A) were planted in 0.2-acre plats (24 rows wide), arranged in a 4×4 latin square. Each whole plat was divided into two sub-plats (12 rows wide), 0.10 acre in size. One sub-plat in each whole plat was secleted at random to be dusted with benzene hexachloride mixture and the other with calcium ar-

[1] The benzene hexachloride mixtures (basic material contained 11.5 per cent gamma isomer) used on experiments Nos. 1, 2 and 3 were furnished by Niagara Sprayer and Chemical Division. The benzene hexachloride mixture (basic material contained 30 per cent gamma isomer) used on experiment No. 4 was furnished by Pennsylvania Salt Manufacturing Co.

senate. The experiment gave 16 adjacent comparisons of the materials, four on each of four varieties. The benzene hexachloride-inert mixture used on the first three applications, from June 14 to 28, contained 7.5 per cent gamma isomer. Due to foliage burn, this material was diluted to a 3.75 per cent gamma isomer mixture for use on the six later applications. This mixture was applied at the average rate of 12 pounds per acre, as compared to calcium arsenate applied at the rate of 9 pounds per acre.

RECORDS.—The infestation records were made at approximately 5-day intervals in the usual manner. One hundred squares were examined on consecutive plants in each plat and the percentage punctured by weevils was recorded. One hundred bolls were examined on consecutive plants in each plat and the percentage injured by bollworms was recorded. Aphid counts were made by recording the number of aphids on a square inch of leaf surface in the center of the fourth leaf from the top, on 100 consecutive plants in each plat. Bollworm eggs were recorded at 5-day intervals on the terminals of 100 consecutive plants in each plat.

RESULTS.—The first bollworm eggs were noted during the first week in July. Records indicated that the numbers were increasing slowly; an average of 29 per 100 terminals was found in experiment No. 2 by July 12. In all the experiments the peak occurred about July 25. No large numbers of eggs were found at any time, but oviposition was continuous from July 12 to July 30. The worms hatching from these eggs caused boll injury from July 20 to August 10. The numbers of eggs found on the plats receiving different treatments did not vary greatly, while the number found on the different varieties did vary considerably. The highest number of eggs was found on the variety in which the highest percentage of injured bolls was found, but in other varieties the number of eggs found was not indicative of the injury.

The seasonal averages of the different

Table 1.—Average insect infestation and yields of seed cotton following treatments as indicated at College Station, Texas, 1946.

TREATMENT	AVERAGE BOLL WEEVIL INFESTATION[1]		AVERAGE BOLLWORM INJURY[2]		NUMBER APHIDS PER SQUARE INCH[3]	POUNDS SEED COTTON		
	Per Cent of Sqs. Punctured	Equivalent Angles	Per Cent of Bolls Injured	Equivalent Angles		Per Plat	Per Acre	Gain Over Check
			Experiment No. 1					
Check	49.5	44.72	8.3	16.69	3.25	43.37	998	
Calcium Arsenate	24.4	29.56	5.8	13.67	8.61	71.48	1644	646
5% DDT-Pyrophyllite	45.7	42.48	3.1	9.80	8.86	51.35	1181	183
Benzene Hexachloride-Inert (5.75% γ isomer)	25.4	30.23	15.5	22.99	.18	64.27	1478	480
Benzene Hexachloride-DDT-Inert (5% DDT and 2.88% γ isomer)	31.4	34.07	2.4	8.72	.70	74.32	1709	711
Minimun significant difference at 5% level		3.09		3.38	5.9	11.1		
			Experiment No. 2					
Check	47.9	43.78	13.0	20.81	1.22	58.35	1459	
Calcium Arsenate	24.5	29.53	5.0	12.60	5.91	84.18	2104	645
5% DDT-Sulphur	52.4	46.37	3.8	11.12	2.22	82.18	2054	595
Benzene Hexachloride-Inert (5.75% γ isomer)	25.2	30.06	27.8	31.70	.11	56.30	1408	−51
Benzene Hexachloride-DDT-Inert (5% DDT and 2.88% γ isomer)	34.0	35.57	3.4	10.51	.17	81.82	2046	587
Minimum significant difference at 5% level		5.67		5.84	3.2	15.8		

[1] Average of 9 records made June 19 to July 30, on experiment 1; average of 4 records made July 18 to Aug. 3, on experiment 2.
[2] Average of 5 records made July 22 to Aug. 10, on experiment 1; average of 5 records made July 24 to Aug. 13, on experiment 2.
[3] Average of 1 record made Aug. 5, on experiment 1; average of 1 record made Aug. 13, on experiment 2.

Table 2.—Average insect infestation and yields of seed cotton following treatments as indicated in Experiment 3 at College Station, Texas, 1946.

Treatment	Average Boll Weevil Infestation[1]		Average Bollworm Injury[2]		Number Aphids per Square Inch[3]	Pounds Seed Cotton		
	Per Cent of Sqs. Punctured	Equivalent Angles	Per Cent of Bolls Injured	Equivalent Angles		Per Plat	Per Acre	Gain Over Check
Check	47.2	43.42	10.6	18.60	1.30	35.0	1050	
Calcium arsenate	26.7	31.06	9.2	17.49	4.00	51.5	1545	495
Calcium arsenate plus 1% Nicotine	29.4	32.82	9.4	17.76	1.44	53.2	1596	546
Benzene hexachloride-Inert Mixtures:								
4.31% γ isomer	30.2	33.86	24.5	29.36	.34	40.8	1224	174
2.88% γ isomer	33.4	35.31	20.4	26.76	1.08	38.7	1161	111
1.44% γ isomer	41.4	40.03	16.8	23.94	.70	37.1	1113	63
Minimum significant difference at 5% level		3.47		4.86	.70	4.8		

[1] Average of 8 records made June 22 to July 26.
[2] Average of 5 records made July 22 to Aug. 13.
[3] Average of 1 record made Aug. 7.

criteria for all experiments are shown in tabular form, and the seasonal infestation data on Experiment No. 4 are shown in figure 1.

In experiment No. 1, the DDT mixture had little or no effect on the weevil; the average infestation was about the same as that found on the checks. Benzene hexachloride mixture containing 5.75 per cent gamma isomer and calcium arsenate were equally effective against the weevil and both were significantly better than the benzene hexachloride-DDT mixture containing only 2.88 per cent gamma isomer and 5 per cent DDT. The 5 per cent DDT mixture and the benzene hexachloride-DDT mixture gave significantly better bollworm control than the other materials. Aphids increased equally on the DDT and calcium arsenate treated plats. Few aphids were found on any of the plats receiving benzene hexachloride. Using yields as the criterion, calcium arsenate, benzene hexachloride-DDT mixture and benzene hexachloride alone were equally effective. In this experiment the weevil was injurious and losses occurred on the DDT treated plats due to the poor control of this pest. A reduction in yield occurred on the benzene hexachloride treated plats due to bollworm injury, but the infestation was not severe enough to make this difference significant. It will be noted that about one-fourth of the gain in yield over the check in this experiment was due to bollworm control and three-fourths resulted from weevil control.

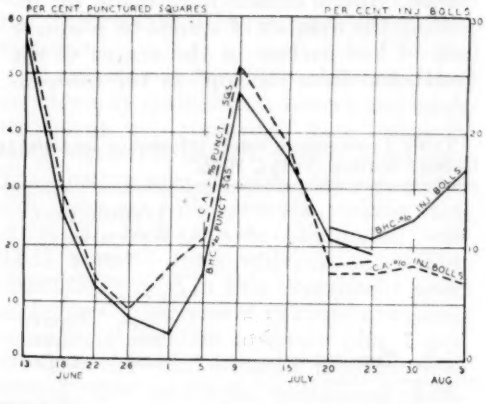

FIG. 1.—The average percentage punctured squares and injured bolls (16 adjacent comparisons on each date) on four varieties of cotton receiving treatments as indicated on the following dates: 6/14, 19, 28, 7/10, 15, 20, 24, 27 and 8/3. Calcium arsenate was applied at the rate of 9 pounds compared to about one-half pound gamma isomer per acre from July 10 to August 3.

The benzene hexachloride mixtures caused skin and nasal irritations to the personnel handling the dusts. These dust mixtures also caused foliage burn at certain times early in the season when the plants were succulent and growthy. This burn was not severe enough to cause losses in production.

Populations of red spiders were observed on plats treated with benzene

Table 3.—Average insect infestation and yields of seed cotton following treatments on the four varieties of cotton as indicated at College Station, Texas, 1946.

	LANKERT		ROGERS ACALA		SHAFTER ACALA		STONEVILLE (4-A)	
	Benzene Hexachloride	Calcium Arsenate	Benzene Hexachloride	Calcium Arsenate	Benzene Hexachloride	Calcium Arsenate	Benzene Hexachloride	Calcium Arsenate
Average boll weevil infestations:[1]								
Per cent of squares punctured	23.47	26.80	18.30	19.02	20.41	22.08	20.61	23.25
Equivalent angles	28.96	31.17	25.14	25.77	23.94	27.95	26.98	28.82
Difference	2.21		.63		4.01		1.84	
Average boll injury:[2]								
Per cent of bolls injured	13.68	7.73	7.75	4.37	7.75	6.75	22.25	10.75
Equivalent angles	21.60	16.02	16.12	11.93	15.46	15.00	28.13	18.71
Difference	−5.58		−4.19		−.46		−9.42	
Average Number aphids per square inch[3]	.52	4.50	.07	2.03	.14	4.29	.11	5.89
Difference	3.98		1.97		4.15		5.78	
Pounds seed cotton:								
Per Plat	69.37	68.92	64.02	72.28	49.27	69.52	59.49	74.62
Per Acre	1387	1378	1280	1446	985	1186	1190	1492
Gain Calcium Arsenate Over Benzene Hexachloride	−9		166		401		302	

[1] Average of 9 records made June 18 to July 25.
[2] Average of 4 records made July 20 to Aug. 5.
[3] Average of 1 record made Aug. 5.

hexachloride and DDT, but not in numbers sufficient to cause injury.

In experiment No. 2, the effects of the treatments against weevil and aphids were similar to those obtained in experiment No. 1, but they reacted somewhat differently against the bollworm. High percentages of bollworm injury occurred on the benzene hexachloride treated plats, reducing the yield to below that of the checks. The increased bollworm injury was possibly due to the effectiveness of the benzene hexachloride against the natural enemies of the bollworm. The 5 per cent DDT mixture did not reduce the weevil infestation, but was effective against the bollworm. Aphids developed on the DDT treated plats but not as fast where sulphur was used as the diluent. Calcium arsenate, DDT and the benzene hexachloride-DDT mixture were equally effective against the bollworm and gave yields which did not differ significantly. In this experiment bollworm control accounted for practically all the gains

Populations of red spiders were noted on the benzene hexachloride treated plats, but this pest was not observed on the DDT treated plats where sulphur was used as the diluent.

In experiment No. 3, the benzene hexachloride mixtures containing 4.31 and 2.88 per cent gamma isomers and calcium arsenate were equally effective against the weevil. The calcium arsenate containing 1 per cent nicotine prevented aphid increases, but did not significantly increase the yield. According to this test, the gamma isomer content of benzene hexachloride mixture should be at least 2.88 per cent adequately to control severe boll weevil infestations.

The increased bollworm injury which occurred on all plats treated with benzene hexachloride mixtures reduced the yield significantly.

In experiment No. 4, the benzene hexachloride mixture containing 3.75 per cent gamma isomer applied at the rate of 12 pounds per acre gave significantly better weevil control than calcium arsenate applied at the rate of 9 pounds per acre. The bollworm injury was greater on the benzene hexachloride treated plats, reducing the yield in certain varieties (Fig. 1). From the analyses of these data, shown in table 4, it will be noted that the treatment-variety interaction was significant for the bollworm injury and yield data. This indicates that the treatments did not react against the bollworm the same in all varieties and that this different reaction affected the yields. These results also indicate that the percentage of injured bolls doesn't in all cases reflect the yield. For instance, in the case of Shafter Acala variety, where the average bollworm injury was practi-

Table 4.—Analyses of data shown in Table 3.

Source of Variation	Degrees of Freedom	Mean Square Pertaining to: Average Punctured Squares (Angles)	Average Bollworm Injury (Angles)	Aphids per Sq. Inch	Yield, Seed Cotton
Whole plats:					
Rows	3	12.55	23.27	6.76	176.00
Columns	3	24.20	25.92	34.42	257.68
Varieties	3	28.80*	142.55†	5.45	161.43
Error (A)	6	4.97	3.90	6.54	127.21
Sub-plats:					
Treatment	1	17.64*	192.91	126.21†	923.43
Treat. vs. Varieties	3	.96	27.42*	4.91	158.21*
Error (B)	12	3.58	6.42	12.64	41.52
Total	31	9.36	30.65	15.22	143.38

* Significant.
† Highly significant.

cally the same on the plats treated with the two insecticides, the average yield was much higher on the calcium arsenate treated plats, while in the Lankart variety the bollworm injury was considerably higher in the benzene hexachloride treated plats, but the yields on the two series of plats receiving calcium arsenate and benzene hexachloride were about the same.

SUMMARY.—Benzene hexachloride mixtures applied at the rate of 11 to 12 pounds per acre, containing as low as 2.88 per cent gamma isomer, proved to be as effective against the weevil as calcium arsenate in one experiment, while in other experiments this percentage gamma isomer was less effective. The mixtures applied at from 11 to 12 pounds per acre, containing at least 5 per cent gamma isomer were equal to or, in one experiment, significantly more effective against weevils than calcium arsenate. Apparently a minimum dosage of 8 ounces of gamma isomer per acre was necessary to give adequate control of severe weevil infestations. Benzene hexachloride, in all concentrations used, prevented aphid increases, but produced increased bollworm injury. Five per cent DDT dust mixtures were effective against the bollworm, but ineffective against weevils and caused aphid increases. Populations of red spiders were noted on both DDT and benzene hexachloride treated plats when sulphur was not used as a diluent. The mixture of DDT and benzene hexachloride was effective against weevils, bollworms and aphids, but did not significantly increase the yields over calcium arsenate.

Benzene hexachloride caused discomfort to personnel handling the material and also produced some foliage burn.

There was a difference in the infestations of weevils and bollworms found in the different varieties. Calcium arsenate and benzene hexachloride did not react the same in the different varieties against the bollworm. This difference in reaction of the insecticides affected the yields.—1-21-47.

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New Insecticides to Control Boll Weevil and Cotton Aphid[1]

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The boll weevil, *Anthonomus grandis* Boh., and the cotton aphid, *Aphis gossypii*, Glov., are the two most important insect pests of cotton in the United States. Calcium arsenate and nicotine for the dual control of the boll weevil and the cotton aphid have been standard recommendations for many years. While these insecticides have been of great value and have in many cases made the profitable production of cotton possible, they are not entirely satisfactory. Therefore, a continuous search has been made in an effort to find an insecticide or a more satisfactory combination of insecticides.

Ivy & Ewing (1946) reported encouraging results in 1945 from the use of benzene hexachloride against several cotton insects. On the basis of these results, the experiments at Florence, South Carolina, during 1946 were centered largely around benzene hexachloride at several strengths, the standard calcium arsenate treatment, and various combinations of benzene hexachloride with both calcium arsenate and basic copper arsenate. Other treatments included in the 1946 experiments were 50 per cent DDT dust, a mixture containing 5 per cent of DDT and 1.43 per cent of gamma-benzene hexachloride, and 50 per cent *Ryania* powder.

Five randomized-block experiments were conducted on plots ranging from 0.2 to 0.1 acre in area, depending on the size and uniformity of the field selected. Two of the experiments included five insecticidal treatments and check replicated four times, and the remaining experiments included six treatments with check areas replicated five times.

All dust applications were made with rotary hand dusting machines in the early morning, usually in the presence of heavy dew. Boll weevil infestation records were made twice weekly and aphid population counts weekly after dusting was begun. Yield records were made in all experiments. Table 1 is a summary of the essential records in these experiments.

Experiment 1 was designed to compare benzene hexachloride at different strengths of the gamma isomer with calcium arsenate alone and with calcium arsenate containing 1 per cent of nicotine. Against the boll weevil both the 5.75 and the 2.87 per cent strengths of gamma-benzene hexachloride were as effective as calcium arsenate, but the 1.43 per cent strength was somewhat less effective. Almost perfect aphid control was obtained with the two highest strengths, and much better control with the 1.43 per cent gamma-benzene hexachloride than with calcium arsenate plus nicotine. The 5.75 per cent treatment effected higher yields than did any other treatment in this experiment. However, the full effect of the two lower strengths is not shown because one plot in each treatment was washed-out.

Experiment 2 was designed to compare calcium arsenate plus benzene hexachloride at different strengths of the gamma isomer with calcium arsenate plus nicotine and with calcium arsenate alone. Briefly, boll weevil control was not affected by the addition of benzene hexachloride or nicotine to calcium arsenate. All treatments were approximately equal in this respect, and all were much superior to the check. The benzene hexachloride apparently broke down when mixed with calcium arsenate and gave no aphid control. Such mixtures are definitely incompatible. Aphid control was much better in the calcium arsenate-nicotine plots than in the others, but was not sufficient to prevent serious damage to the cotton. Because of the aphid build-up which reduced yields considerably in all the treated plots, yield records are not of much value in this experiment.

Experiment 3 was designed to compare three different benzene hexachlorides, each containing 2.87 per cent of the gamma isomer but manufactured by different processes, with calcium arsenate, basic copper arsenate, and DDT plus benzene hexachloride. There was very little difference in degree of boll weevil infestation following the various treatments. The benzene hexachloride No. 2 had the lowest average, but caused considerable burning of the foliage. Aphid control with the different benzene hexa-

[1] Cotton States Branch Program paper.

Table 1.—Results of five randomized-block experiments testing various insecticides against the boll weevil and cotton aphid, Florence, S. C. 1946.

Treatments	Pounds per Acre-Application	Average Per Cent of Boll Weevil Infestation	Maximum Aphids per Leaf	Average Pounds of Seed Cotton per Acre	Increase Seed Cotton per Acre over Check
Experiment 1—8 applications beginning at 20% boll weevil infestation, 8 boll weevil infestation records, 8 aphid counts					
Calcium arsenate	8.0	42.6	119.6	1513	456
Calcium arsenate plus nicotine 1%	7.2	42.4	15.3	1556	499
Gamma-benzene hexachloride 5.75%	6.4	42.2	0.9	1670	613
2.87%	10.1	39.6	0.8	1214	157
1.43%	9.2	46.8	2.6	1155	98
Check	—	60.4	8.1	1057	
Experiment 2—8 applications beginning at 10% boll weevil infestation, 10 boll weevil infestation records, 8 aphid counts					
Calcium arsenate	8.4	22.9	130.5	1564	292
Calcium arsenate plus—					
Nicotine 1%	7.7	23.9	69.5	1301	29
Gamma-benzene hexachloride 1.43%	9.6	22.2	123.5	1291	19
0.72%	10.2	23.0	132.0	1440	168
0.36%	8.4	24.5	124.8	1466	194
Check	—	51.8	49.9	1272	
Experiment 3—7 applications beginning at 30% boll weevil infestation, 8 boll weevil infestation records, 7 aphid counts					
Calcium arsenate	9.1	30.2	90.8	1213	332
Basic copper arsenate	9.7	36.7	92.6	1166	285
Gamma-benzene hexachloride 2.87% No. 1	10.2	35.7	0.7	1271	390
No. 2	17.4	26.7	1.0	1130	249
No. 3	11.0	33.3	0.8	1103	222
DDT 5% plus gamma benzene hexachloride 1.43%	12.6	29.6	1.7	1334	453
Check (outside)	—	65.0	—	881	
Experiment 4—8 applications beginning at 20% boll weevil infestation, 8 boll weevil infestation records, 6 aphid counts					
Calcium arsenate	9.1	32.1	124.6	1681	415
Calcium arsenate plus nicotine 1%	9.0	28.1	23.5	1821	555
Basic copper arsenate	9.4	34.8	140.0	1657	391
Basic copper arsenate plus—					
Rotenone 0.5%	7.9	28.5	50.1	1714	448
Gamma-benzene hexachloride 1.43%	9.0	30.5	22.6	1523	257
0.72%	7.7	31.3	60.4	1602	336
Check (outside)	—	62.2	—	1266	
Experiment 5—9 applications beginning at 10% boll weevil infestation, 9 boll weevil infestation records, 5 aphid counts					
Calcium arsenate	11.4	33.2	117.8	1576	208
Basic copper arsenate	9.6	34.2	119.5	1858	490
Gamma-benzene hexachloride 1.0%	11.9	34.6	4.8	2035	667
5.75%	10.6	31.9	0.7	1852	484
Ryania powder 50%	6.3	46.6	57.3	1626	258
DDT 50%	6.9	38.6	70.6	2306	938
Check (outside)	—	63.2	—	1368	

chlorides, alone and with DDT, was nearly perfect, but both calcium arsenate and basic copper arsenate allowed heavy populations of aphids to develop. The most outstanding treatment in this experiment, from the standpoint of yields, was DDT plus benzene hexachloride. It apparently had greater residual effect against the boll weevil, and probably the bollworm and other cotton insects, than any of the others. More bolls developed in the tops of the plants receiving this treatment. The benzene hexachloride No. 1 gave slightly greater yields than calcium arsenate. All treatments resulted in significant increases in yield.

Experiment 4 was designed to compare calcium arsenate, calcium arsenate plus nicotine, basic copper arsenate, basic copper arsenate plus rotenone, and different strengths of the gamma isomer of benzene hexachloride. Each treatment proved to be highly effective against the boll weevil, with no important differences between treatments. Satisfactory aphid control was not secured with any of the treatments, although calcium arsenate with nicotine and basic copper arsenate with 1.43 per cent of gamma benzene hexachloride gave much better control than the others. The other combinations gave better control than either of the arsenicals alone. All treatments gave yields greatly superior to the check, the calcium arsenate with nicotine being the best and basic copper arsenate with rotenone next. Combinations of basic copper arsenate and benzene hexachloride do not appear to be practical for simultaneous control of boll weevil and cotton aphid, although such materials are not wholly incompatible, as are calcium arsenate and benzene hexachloride.

Experiment 5 was designed to compare calcium arsenate, basic copper arsenate, benzene hexachloride at different strengths of the gamma isomer, *Ryania* powder, and DDT. Both arsenicals and all strengths of benzene hexachloride were approximately equally effective against the boll weevil, and all gave very good control. DDT was only slightly less effective against the boll weevil than were these four treatments, and was much more effective than *Ryania* powder, which was itself more effective than the check. The 5.75 per cent gamma-benzene hexachloride gave almost perfect aphid control. The 1.0 per cent strength was nearly as good, and was 11 times as effective as *Ryania* powder, which gave twice as good control as did either of the arsenicals, and slightly better than DDT.

The yield records in this experiment were the most significant. Calcium arsenate brought about the least increase in yield, owing almost entirely to the aphid build-up which caused most of the leaves and many of the young bolls to shed. Basic copper arsenate gave rise to a little higher aphid population than did calcium arsenate, but did not cause the leaf or boll shed that calcium arsenate did. However, this is not always true. It is probable that under certain conditions the cotton plant absorbs the copper in the basic copper arsenate and utilizes it as a nutrient. Higher yields resulted from the use of the 1.0 per cent gamma-benzene hexachloride than from the 5.75 per cent. The two materials were from different sources. *Ryania* powder resulted in somewhat higher yields than calcium arsenate, owing to better aphid control. From the standpoint of yields DDT was the most promising insecticide tested. Apparently this was due to its residual toxicity to the bollworm and other insects. The cotton plants in plots that received DDT were the only ones which had open bolls to their very tops.

SUMMARY.—Field experiments were conducted at Florence, South Carolina, to compare the effect of several insecticides and combinations of insecticides, including benzene hexachloride and DDT, against the boll weevil and the cotton aphid. Benzene hexachloride gave almost perfect aphid control at strengths from 1.00 to 5.75 per cent of the gamma isomer when mixed with an inert diluent or with DDT. Benzene hexachloride and calcium arsenate were incompatible, the benzene hexachloride apparently breaking down completely. Benzene hexachloride and basic copper arsenate appeared to be partially incompatible, the aphid control being somewhat less when they are used together than when similar strengths of benzene hexachloride were mixed with an inert diluent. For boll weevil control, benzene hexachloride at strengths of 1.0 to 5.75 per cent of the gamma isomer compared favorably with calcium arsenate. Mixtures of DDT and benzene hexachloride were more promising than benzene hexachloride alone. *Ryania* powder (50 per cent) did not compare favorably with calcium arsenate, benzene hexachloride, or DDT. DDT seemed to be very promising for the control of many of our cotton insects. From the standpoint of increased yields, 50 per cent DDT was the best material tested.

LITERATURE CITED

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Cotton-Insect Control with Benzene Hexachloride, alone or in Mixture with DDT

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Experiments at the Waco, Texas, laboratory of the Bureau of Entomology and Plant Quarantine in 1945 showed that benzene hexachloride was the most promising all-round insecticide thus far tested for control of cotton insects, with the important exception that it did not control the bollworm (Ivy & Ewing 1946). In 1946 many experiments were conducted at Waco with benzene hexachloride, alone or in mixture, and other insecticides against the boll weevil, *Anthonomous grandis* Boh., the cotton aphid, *Aphis gossypii* Glov., the cotton leafworm, *Alabama argillacea* (Hbn.), the bollworm, *Heliothis armigera* (Hbn.), and insects of less importance.

Materials Used.—Most of the benzene hexachloride was obtained from the manufacturer as a 50 per cent mixture with gypsum, the mixture reported by the manufacturer to contain 5.75 per cent of the gamma isomer. When this concentration was used, 3 per cent of *Celite* was added to improve the dusting qualities of the mixture. The following isomers were also reported by the manufacturer to be present: Alpha 35, beta 3.5, and delta 4 per cent. When the concentration was less than 5.75 per cent, pyrophyllite or sulfur was used as a diluent. Mixtures of benzene hexachloride with calcium arsenate and with DDT were used in some experiments. Some benzene hexachloride was also obtained from various manufacturers in 50 per cent mixtures with talc, clays, or unknown diluents. These mixtures were reported to contain 5 per cent of the gamma isomer, with the exception of small amounts of some special mixtures which were used in the laboratory and cage tests.

The standard commercial calcium arsenate was used except in certain experiments in which so-called "neutral" calcium arsenate[3] was used in mixtures with benzene hexachloride.

The nicotine in the calcium arsenate-nicotine mixtures was a commercial dust containing 14 per cent of soluble nicotine. Nicotine sulfate was used in the nicotine-lime mixtures. Unless otherwise stated DDT dusts contained pyrophyllite. The cryolite-sulfur dust contained 61 per cent of sodium fluoaluminate.

Boll Weevil.—*Destructiveness and migrations of overwintered boll weevils.* Throughout most of central Texas only about 25 per cent of the total cotton acreage for 1946 was planted during April and early May, the normal seeding period. Naturally the overwintered weevils concentrated in this small acreage of early planted cotton. Until nearly the end of June fruiting buds (squares) were attacked and destroyed by boll weevils almost as fast as they formed, with the result that in many fields cotton plants reached a height of 2 feet or more before large squares developed, and the plants had the appearance of having been attacked by cotton fleahoppers.

An example of the destructiveness of the overwintered boll weevils and of their migration in search of large squares for food and egg deposition was observed in one experiment. In a 12-acre field of early planted cotton 1 acre was dusted five times between May 2 and June 7 with benzene hexachloride for boll weevil control. Excellent control was secured; on June 14 the dusted plot averaged 3.7 large squares per plant and the undusted plot 0.7 square. Because the dusted plot had five times as many squares per plant as the undusted plot, the boll weevils began to migrate into the dusted plot. Approximately 2 weeks later, or on June 27, there were 1410 weevils per acre in the dusted cotton and 152 per acre in the undusted. In other words, there were nine times as many boll weevils in the dusted cotton, where squares were abundant, as in the undusted cotton, where squares were scarce. This may explain, at least partially, the many failures that have occurred in pre-square or early season boll weevil control when attempted on a small

[1] In cooperation with the Texas Agricultural Experiment Station.
[2] "Paid Paper."
[3] Analysis of this "neutral" calcium arsenate by the Division of Insecticide Investigations of the Bureau of Entomology and Plant Quarantine showed that it actually contained 1 per cent of free lime.

scale or on less than a plantation or community-wide basis.

PRE-SQUARE EXPERIMENTS.—Seven pre-square experiments were conducted during May and June in early planted cotton to compare the effectiveness of benzene hexachloride and calcium arsenate against overwintered boll weevils. The plots were dusted from one to three times at approximately weekly intervals, at the rate of 8 pounds per acre. Although entire fields, ranging from 1.5 to 6 acres, were utilized, the overwintered weevils were so persistent in their efforts to find large squares on which to feed and in which to lay eggs that there was a more or less continuous migration from field to field throughout June, and the dusted fields were reinfested within a few days. Infestation records made 24 hours after dusting showed that benzene hexachloride gave a much quicker kill than calcium arsenate.

The boll weevil population per acre was computed from examination of plants on 500 feet of row. In one experiment the population 24 hours after dusting with benzene hexachloride containing 5.75 per cent of gamma isomer was reduced from 1248 to 29 weevils per acre, or 97.7 per cent, and in another similar experiment the reduction was from 1452 to 15 boll weevils, or 99 per cent. The average of five experiments is shown in table 1. Examinations made 6 days after the insecticides were applied showed that benzene hexachloride containing 5.75 per cent of gamma isomer gave better control than did calcium arsenate, but that the 2.88 per cent concentration was less effective.

CAGE EXPERIMENTS TO DETERMINE DURATION OF EFFECTIVENESS.—To obtain further information on the duration of effectiveness of benzene hexchaloride, a series of cage tests was conducted. On July 3 two similar groups of field-growing cotton plants were dusted, one with calcium arsenate and one with benzene hexachloride (5.75 per cent gamma isomer), each at the rate of 8 pounds of dust per acre. Immediately after the dusting, and again after 2 and 4 days, 4 plants of each group were individually caged and 35 to 40 boll weevils were released in each cage. Examinations were made for 5 days following each release to determine the boll weevil mortalities.

Table 1.—Average per cent reduction of boll weevil infestation following treatments with benzene hexachloride and calcium arsenate.

TREATMENT	AFTER 24 HOURS (5 EXPERIMENTS)	AFTER 6 DAYS (7 EXPERIMENTS)
Benzene hexachloride:		
Gamma 5.75%	79.7	73.3
Gamma 2.88%	69.8	56.7
Calcium arsenate	16.3	65.7

It will be noted (Table 2) that benzene hexachloride gave a much quicker kill than did calcium arsenate, but that it lost its high toxicity to boll weevils after about 2 days.

COOPERATIVE SMALL-PLOT EXPERIMENT.—This experiment, conducted for boll weevil and cotton aphid control, compared three concentrations of benzene hexachloride with calcium arsenate alone and with calcium arsenate plus 1 per cent of nicotine. Similar experiments were conducted by Bureau workers at Florence,

Table 2.—Per cent mortality of boll weevils at various intervals after release in cages treated with benzene hexachloride (gamma isomer 5.75 per cent) and with calcium arsenate.

TIME AFTER DUSTING TO RELEASE	TREATMENT	DAY				
		1st	2nd	3rd	4th	5th
Immediately	Benzene hexachloride	36.4	77.8	82.6	86.0	89.3
	Calcium arsenate	10.3	29.9	52.3	78.5	88.8
	Untreated check	0	0	0	1.6	3.9
2 days	Benzene hexachloride	15.3	27.3	32.0	33.3	34.7
	Calcium arsenate	6.5	23.4	38.3	54.2	69.2
	Untreated check	1.7	2.6	4.3	5.2	6.9
4 days	Benzene hexachloride	5.1	9.6	11.0	15.4	18.4
	Calcium arsenate	12.6	16.2	25.2	30.6	36.9
	Untreated check	0	1.9	1.9	1.9	6.5

Table 3.—Effectiveness of benzene hexachloride and a mixture of benzene hexachloride and DDT against boll weevils, bollworms, and cotton aphids.

Treatment	Rate of Application per Acre	Boll Weevil Punctured Squares	Bollworm Infestation		Aphids per Square Inch		Yield of Seed Cotton per Acre	
			Injured Squares	Injured Bolls	Average	Maximum	Total	Gain Over Check
	Pounds	*Per Cent*	*Per Cent*	*Per Cent*	*Number*	*Number*	*Pounds*	*Pounds*
Experiment 1 (small-plot, boll weevil and cotton aphid)								
Benzene hexachloride:								
Gamma 5.75%	8.0	18.6	13.1	18.0	1.3	7.3	1488	46
2.88%	7.8	24.7	10.4	10.0	2.2	11.7	1526	84
1.44%	8.5	29.7	10.3	8.6	2.7	13.2	1469	27
Calcium arsenate	7.6	17.9	10.4	8.9	4.5	18.4	1334	−108
Calcium arsenate plus nicotine 1%	8.0	19.2	10.5	9.4	3.2	13.2	1408	−34
Untreated check	—	41.4	10.0	8.3	2.3	11.8	1442	—
Difference required for significance, 5% level	—	4.9	—	—	1.0	—	—	—
Experiment 2 (small-plot, bollworm and cotton aphid)								
Benzene hexachloride, gamma 5.75%	15.1	6.1	40.5	48.2	2.9	5.6	31	−58
DDT 10%	16.4	15.8	6.5	6.0	10.5	24.0	916	827
DDT 5%	16.5	16.5	10.9	13.7	11.3	25.6	635	546
DDT 5% plus sulfur 82.5%	16.8	17.5	15.2	19.8	6.1	14.7	503	414
Cryolite 70% plus sulfur 30%	16.4	13.3	17.2	17.8	6.5	16.1	524	435
Untreated check	—	15.5	32.0	45.3	8.2	17.1	89	—
Difference required for significance, 5% level	—	6.3	8.4	9.9	4.1	—	179	—
Experiment 3 (small-plot, bollworm and cotton aphid)								
Benzene hexachloride, gamma 4.31%	16.2	1.1	33.2	37.9	4.3	8.4	202	58
Benzene hexachloride, gamma 4.31%, plus DDT 5%	18.1	1.3	7.7	3.6	2.2	4.1	1284	1140
DDT 5%	15.6	1.3	11.6	12.4	24.3	38.1	678	534
DDT 10%	7.6	0.8	12.1	10.1	26.0	41.2	636	492
Calcium arsenate	16.1	1.4	11.7	13.1	25.4	40.8	704	560
Untreated check	—	1.2	31.9	37.3	29.0	39.8	144	—
Difference required for significance, 5% level	—	—	7.7	6.6	7.8	—	153	—
Experiment 4 (large-scale, bollworm, aphid, and boll weevil)								
Benzene hexachloride, gamma 2.88%, plus DDT 5%	15.8	6.8	12.9	11.0	1.4	6.5	1276	1114
Benzene hexachloride, gamma 0.575%, plus calcium arsenate	8.8	3.1	20.1	27.9	10.2	25.5	236	74
Calcum arsenate	15.3	4.4	12.2	19.6	13.7	28.0	774	612
Calcium arsenate	8.6	2.5	17.2	28.2	14.5	42.6	442	280
Calcium arsenate plus nicotine 1%	9.0	5.6	18.3	30.6	8.1	20.8	441	279
Untreated check	—	18.3	31.4	39.2	8.4	19.9	162	—
Experiment 5 (large-scale, bollworm, aphid and boll weevil)								
Benzene hexachloride, gamma 2.88%, plus DDT 5%	16.2	0.5	5.7	5.3	1.4	5.2	1753	
Benzene hexachloride, gamma 1.15%, plus calcium arsenate	15.5	0.4	11.2	9.3	18.3	28.9	824	
Calcium arsenate	15.6	1.2	9.3	7.8	12.8	31.7	927	
Calcium arsenate plus nicotine 2%[1]	15.3	0.9	12.6	10.8	3.2	11.7	1189	

Table 3.—(Continued)

Treatment	Rate of Application per Acre	Boll Weevil Punctured Squares	Bollworm Infestation		Aphids per Square Inch		Yield of Seed Cotton per Acre	
			Injured Squares	Injured Bolls	Average	Maximum	Total	Gain Over Check
	Pounds	*Per Cent*	*Per Cent*	*Per Cent*	*Number*	*Number*	*Pounds*	*Pounds*
Experiment 6 (large-scale, bollworm, aphid, and boll weevil)								
Benzene hexachloride, gamma 2.88%, sulfur 37%, and DDT 5%	15.4	1.8	8.3	5.4	0.2	0.7	1184	1085
Untreated check	—	1.9	44.9	39.0	4.7	11.5	99	
Experiment 7 (large-scale, bollworm, aphid, and boll weevil)								
Benzene hexachloride, gamma 2.88%, sulfur 37%, DDT 5%	15.9	5.2	7.3	6.4	0.4	1.2	1105	756
Benzene hexachloride, gamma 4.5%, clay and unknown inert 50%, and DDT 5%	16.3	1.0	3.9	4.7	0.1	0.1	1305	956
Calcium arsenate	15.6	7.0	17.3	11.6	5.4	8.9	514	165
DDT 5% in sulfur	15.6	32.1	6.2	7.0	4.1	10.6	675	326
Untreated check	—	25.1	19.5	21.7	5.7	12.5	349	—

[1] First 3 applications and their alternate applications with calcium arsenate alone.

S. C., Stoneville, Miss., Tallulah, La., San Benito, Texas, and by state experiment station personnel at Shreveport, La., and College Station, Texas. The plots were 18 rows wide and 0.2 acre in size, and were arranged in randomized blocks with four replications of each treatment. The dusts were applied on June 27, July 3, and July 31, with rotary hand guns, and the procedure and method of recording data were the same as had been previously reported (Ewing & Parencia 1943). The treatments and experimental data are shown in table 3, experiment 1. Heavy infestations of bollworms made it necessary to dust all plots, including check plots, with 5 applications of 5 per cent DDT in pyrophyllite between July 13 and August 10 to prevent the bollworm from ruining the experiment.

Each insecticidal treatment reduced the boll weevil infestation significantly below that in the check. According to the infestation records, calcium arsenate alone, calcium arsenate plus 1 per cent of nicotine, and benzene hexachloride containing 5.75 per cent of the gamma isomer were significantly better than the lower concentrations of gamma-benzene hexachloride in controlling the boll weevil; however, the yield records showed no significant difference between treatments. Continued hot, dry weather and widespread dusting of surrounding cotton for boll weevil control reduced weevil damage in the check plots to a minimum, the infestation being 87 per cent on June 26 and 19 per cent on July 16.

LARGE-SCALE EXPERIMENTS.—Several large-scale experiments for boll weevil control in which benzene hexachloride was used were conducted but are not reported in detail in this paper. There was a fairly high boll weevil infestation in large-scale experiment 7, as may be noted in table 3. Boll weevils were also very numerous in two other experiments in which benzene hexachloride mixed with DDT was used. Field-plot experimental data show that satisfactory boll weevil control may be obtained from benzene hexachloride, alone or mixed with DDT.

TOXICITY OF BENZENE HEXACHLORIDE FROM DIFFERENT MANUFACTURERS.—Cage tests were conducted with six samples of benzene hexachloride, each reported by the manufacturer to contain

5 per cent of the gamma isomer. Five were of American manufacture and one was manufactured in England. All these samples were tested against boll weevils, bollworms, and cotton leafworms, and four were tested against cotton aphids. The numbers of insects tested with the various materials ranged as follows: Boll weevils 195 to 217, bollworms 67 to 84, cotton leafworms 170 to 200, and cotton aphids 728 to 1196. The rates of application per acre were 8 pounds for boll weevils, 16 pounds for bollworms and leafworms, and 10 pounds for cotton aphids. Results of these tests are shown in table 4.

Against cotton aphids and leafworms all samples were about equally effective. Against boll weevils the variation was more marked, and against bollworms there was a wide range of effectiveness.

Table 4.—Per cent mortality of boll weevils, bollworms, and cotton leafworms 5 days after dusting and of cotton aphids 24 hours after dusting with various commercial dusts containing benzene hexachloride (gamma isomer 5 per cent).

Sample	Boll Weevil, Adults	Bollworm, Third Instars	Cotton Leafworm, Third Instars	Cotton Aphids
1	92	45	92	—
2	89	51	96	76
3	87	68	99	74
4	86	55	93	78
5	82	44	98	—
6	77	33	98	79

BOLLWORM EXPERIMENTS.—The extremely heavy damage from bollworms in many cotton fields in central Texas during 1946 gave excellent opportunity for field tests with the new insecticides.

Two small-plot experiments were conducted near Waco for control of this insect in which DDT, benzene hexachloride, and a mixture of these two insecticides were used. The plots were 10 rows wide and 0.1 acre in size, and were arranged in randomized blocks with four replications of each treatment. The dusts were applied and data recorded in a similar manner as in the boll weevil and aphid experiments. The treatments and experimental data are shown in table 3, experiments 2 and 3.

In experiment 2 five dust applications were made between July 18 and August 14. In previous experiments (Parencia *et al.* 1946) 10 per cent DDT gave better, but not significantly better, control than 5 per cent DDT. Owing perhaps to the extremely heavy bollworm infestation in this experiment, where the check produced only 89 pounds of seed cotton per acre, the 10 per cent DDT gave significantly better control of the bollworm than the 5 per cent. The plots treated with 5 per cent of DDT in pyrophyllite produced more, but not significantly more, than 5 per cent of DDT in sulfur, or than cryolite. Benzene hexachloride alone was of no value in controlling the bollworm. In fact, there was an increased infestation and lower a yield in the plots treated with benzene hexachloride than in the check.

In experiment 3 five dust applications were made between July 27 and August 17. Infestation and yield records (Table 3) show that the mixture of DDT and benzene hexachloride gave excellent bollworm control. The gain from the mixture was slightly more than twice that from the 5 per cent DDT. There was no significant difference between 5 per cent DDT at approximately 16 pounds, 10 per cent DDT at about 8 pounds, and calcium arsenate at 16 pounds per acre. Benzene hexachloride alone at 16 pounds per acre was totally ineffective.

Results of experiments 2 and 3 indicate that benzene hexachloride should not be used alone for cotton insect control where the bollworm may be involved.

LARGE-SCALE EXPERIMENTS.—In experiment 4 dusts were applied three times between July 10 and 19, with light dosages (6 to 8.7 pounds per acre) for boll weevil control. The treatments consisted of benzene hexachloride, a mixture of calcium arsenate and benzene hexachloride, calcium arsenate containing 1 per cent of nicotine, and calcium arsenate alone. Dusting was done with a 6-row tractor-attachment dusting machine. Each plot was 36 rows wide and 4.1 acres in size. By July 24, boll weevils were below the damage point in all plots; therefore, the design of the experiment was changed to control the heavy bollworm infestation that had developed. The three previous treatments had little if any effect upon the results obtained from the experi-

ment. Beginning July 24, the plot that had been dusted with benzene hexachloride alone received a mixture of DDT and benzene hexachloride. Seven applications, six effective, were made between July 24 and August 21 for bollworm control. Treatments and all experimental data are shown in table 3.

The mixture of DDT and benzene hexachloride gave very good results in the control of bollworms, aphids, and boll weevils, the gain in yield being almost twice as much as from calcium arsenate at approximately 16 pounds per acre. The gain from calcium arsenate at 16 pounds was more than twice that at 8 pounds.

Experiments 5, 6, and 7 (Table 3) were begun late in the season, in cotton that had previously been dusted by the owners five to seven times with calcium arsenate or with calcium arsenate followed by 5 per cent DDT for boll weevil and bollworm control. The experiments were in separate fields. The owners had abandoned hope of producing a crop in these fields, because aphids were so abundant and bollworms had destroyed about all the squares and bolls of what had promised to be a bale-per-acre crop before the bollworm struck.

The plots in experiment 5 received six effective applications between August 7 and September 7, those in experiment 6 received six applications between August 16 and September 12, and those in experiment 7 received seven between August 17 and October 1. All applications were made with 6-row or 8-row tractor-attachment dusting machines, except the last in experiment 7, which was by airplane.

In experiment 5 and 6 the cotton dusted with the mixture of DDT and benzene hexachloride showed the most marked recovery from insect damage, and the most phenomenal increase in vigor and fruiting, of any dusted cotton ever observed by the authors. Within a remarkably short time the plants were covered from top to bottom with blooms and bolls. In experiment 7 the recovery was somewhat slower but nonetheless evident, whereas adjoining cotton dusted with calcium arsenate appeared lifeless and did not put on new fruit for some time. There was a killing frost on October 12, which prevented further fruiting and damaged many of the immature bolls in nearly all the dusted plots of the late-season experiments. Because the frost-damaged bolls did not open into harvestable cotton, the gains in yields were considerably reduced.

The plots treated with the mixture of 5 per cent DDT and benzene hexachloride containing 2.88 per cent of the gamma isomer produced enormous gains over the untreated plots and over those treated with calcium arsenate or with calcium arsenate plus 2 per cent of nicotine.

COTTON APHID.—Frequently when small plots, portions of fields, or isolated fields are dusted with calcium arsenate or other "aphid-building" insecticides, no serious damage from aphids occurs, because predators and parasites from undusted areas nearby migrate into the relatively small dusted areas. On the other hand, when practically all the cotton in large fields on entire farms or throughout entire communities is dusted, aphids usually build up in large numbers. Dusting the early planted cotton with calcium arsenate for boll weevil control was general during 1946 in certain communities around Waco and throughout central Texas. As a result aphids built up in damaging numbers, and migration was widespread. In many communities the undusted as well as the dusted cotton became heavily infested. It was under such heavy aphid migrations that nicotine sulfate and benzene hexachloride were tested at Waco in 1946.

Aphid population counts were made in all field-plot experiments. Results of some of these counts are shown in table 3.

In experiment 2 when sulfur was mixed with DDT the aphid infestation was only about half as great as when pyrophyllite was used.

In experiment 3 benzene hexachloride alone and in a mixture with DDT gave excellent aphid control. The infestation in the treatment receiving the mixture was approximately one-half of that in the treatment receiving benzene hexachloride alone, but this difference was not significant. Much better bollworm control was noted from the mixture than from 5 per cent DDT. It appears that the mixture of DDT and benzene hexachloride is more effective against aphids than benzene hexachloride alone, and more effective against bollworms than DDT alone. The reason for this greater effectiveness is not

clear, but the possibility of synergism should not be overlooked.

Aphids did considerable damage in all plots of experiment 4 except the plot dusted with the mixture of DDT and benzene hexachloride. This mixture gave excellent control of aphids, bollworms, and leafworms. Calcium arsenate mixed with nicotine in every application failed to give satisfactory control.

In experiment 5, 2 per cent of nicotine in calcium arsenate for the first three successive applications and then alternate applications with calcium arsenate alone did not give nearly so good knock-out or continued control of a heavy aphid infestation as did a mixture of DDT and benzene hexachloride.

Experiments 6 and 7 were also begun when there was a heavy initial infestation of aphids, and the mixture of DDT and benzene hexachloride gave satisfactory results. In fact, in every experiment where aphids were extremely difficult to control benzene hexachloride or a mixture of benzene hexachloride and DDT was satisfactory, not only in preventing a build-up within the dusted area, but also as a knock-out in controlling heavy infestations of aphids.

A small-plot randomized-block experiment with four replicates of each treatment was conducted to compare 3 per cent of nicotine in lime and benzene hexachloride dusts containing 5, 2.5, and 1.25 per cent of the gamma isomer. At the time the experiment was begun there was a heavy aphid infestation. Approximately 10 pounds per acre of each dust was applied on July 17. Examinations made after 1 and 3 days showed that only the benzene hexachloride containing 5 per cent of the gamma was more effective than nicotine in lime.

In a small-plot experiment three calcium arsenate-benzene hexachloride dusts —0.36, 0.72, and 1.44 per cent of gamma isomer—applied eight times at 8 pounds per acre, gave no appreciable aphid control. These records indicate an incompatibility between the two insecticides.

Benezene hexachloride was mixed with a so-called "neutral" calcium arsenate in experiments 4 and 5 (Table 3). These mixtures likewise failed to give a satisfactory aphid control at concentrations of either 0.575 or 1.15 per cent of the gamma isomer.

A mixture of benzene hexachloride and a special calcium arsenate, reported by the manufacturer to contain no free lime, was effective against cotton aphids, boll weevils, and bollworms in preliminary laboratory and cage tests.

LEAFWORM.—Most of the experimental plots became infested with leafworms in September, which state afforded an opportunity for a study of the effect of benzene hexachloride on this insect under field conditions. In several experiments where five applications of benzene hexachloride had been made before leafworms appeared, the residual control was surprisingly good. In some of these experiments cotton was protected from leafworm defoliation for 8 weeks after the last dust application, or until defoliated by frost. Adjacent undusted cotton and cotton dusted with calcium arsenate, cryolite, or DDT were completely defoliated. The mixture of DDT and benzene hexachloride appeared to give control of the leafworm equal to that given by benzene hexachloride alone, if not slightly better.

OTHER INSECTS.—Records and observations made in the various field experiments showed that benzene hexachloride or a mixture of DDT and benzene hexachloride was effective in controlling the cotton fleahopper, *Psallus seriatus* Reut., the rapid plant bug, *Adelphocoris rapidus* (Say), thrips, stink bugs, and loopers.

TWO-SPOTTED SPIDER MITE.—The two-spotted spider mite, *Tetranychus bimaculatis* Harvey, better known as the red spider, increased in some of the experiments in which benzene hexachloride, DDT, or a mixture of these two insecticides was used. In experiments 4 and 7 the infestation approached the damage point in the plots dusted with the mixture without sulfur. The addition of sulfur in experiment 7 aided in checking the increase of this mite.

SUMMARY OF RESULTS.—In field-plot experiments at Waco, Texas, during 1946 benzene hexachloride dust containing at least 5 per cent of the gamma isomer gave satisfactory control of the boll weevil, *Anthonomus grandis* Boh., the cotton aphid, *Aphis gossypii* Glov., and the cotton leafworm, *Alabama argillacea* (Hbn.), but no control of the bollworm, *Heliothis armigera* (Hbn.). Mixtures of 5 per cent DDT and benzene hexachloride containing from 2.88 to 4.31 per cent of the gamma

isomer gave excellent control of the bollworm and were also effective in controlling the boll weevil, cotton aphid, and cotton leafworm. These mixtures were more effective against the bollworm than was DDT alone, against the cotton aphid and cotton leafworm than benzene hexachloride alone, and in several late-season experiments gave adequate control of heavy infestations of the boll weevil.

In one small-plot experiment a mixture of 5 per cent DDT and benzene hexachloride containing 4.31 per cent of the gamma isomer produced 1284 pounds of seed cotton per acre, as compared with 678 pounds from 5 per cent DDT alone and 144 pounds from the untreated check. In a large-scale experiment begun when the bollworm infestation first developed, a plot treated with a mixture of 5 per cent DDT and benzene hexachloride containing 2.88 per cent of the gamma isomer produced a gain, over the check, of 1114 pounds. The gain from the mixture was almost twice as much as from calcium arsenate at approximately 16 pounds per acre, and calcium arsenate at 16 pounds produced a gain of more than twice as much as calcium arsenate at 8 pounds.

Three late-season large-scale experiments with a mixture of 5 per cent DDT and benzene hexachloride containing 2.88 per cent of the gamma isomer were conducted in cotton fields in which the growers had failed to control the bollworm. At the time the experiments were begun, the cotton plants were practically devoid of fruit and were heavily infested with aphids. In one experiment the production was 1184 pounds per acre as compared with 99 pounds in the untreated check. In another experiment with this mixture there was a gain of 756 pounds per acre over the untreated check and a gain of 591 pounds over the plot treated with calcium arsenate. In a third experiment this mixture effected a gain of 826 pounds over calcium arsenate and a gain of 564 pounds over calcium arsenate plus 2 per cent of nicotine.

In cage and field tests benzene hexachloride gave a much quicker kill of the boll weevil than did calcium arsenate, but it lost most of its toxicity within about 2 days. On the other hand, against cotton leafworms its effect was much more residual than was that of calcium arsenate.

There was evidence that benzene hexachloride may be incompatible with standard calcium arsenate.

As a knock-out aphicide benzene hexachloride containing 5 per cent of the gamma isomer was more effective than 3 per cent of nicotine in lime, but benzene hexachloride containing 2.5 per cent of the gamma isomer was less effective. When mixed with 5 per cent DDT, benzene hexachloride containing 2.88 per cent of the gamma isomer was approximately twice as effective against a heavy aphid infestation as was 2 per cent of nicotine in calcium arsenate.

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Entomologists to Meet in Chicago

The annual meetings of the American Association of Economic Entomologists and the Entomological Society of America will be held in Chicago December 27 to December 30. Headquarters will be at the Congress Hotel and reservations should be made early.

Benzene Hexachloride for Control of Plum Curculio on Peaches

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Although, prior to 1946, nothing had been published on the use of benzene hexachloride for the control of the plum curculio on peaches, reports were circulated that it was effective against that insect. Preliminary experiments were therefore conducted at Fort Valley, Ga., during 1946 to determine the effect of this new insecticide on the plum curculio and on peach fruit and foliage. These included cage tests, single-tree tests, tests in commercial-orchard plots and also preliminary experiments in treating peach drops and soil.

Several commercial formulations of benzene hexachloride were used. The composition of those prepared from a technical grade of the material was reported to be as follows: (1) A 31.6 per cent wettable powder containing 3.79 per cent of the gamma isomer, (2) a 5 per cent dust containing 0.575 per cent of the gamma isomer, and (3) a 10 per cent dust containing 1.15 per cent of the gamma isomer. The composition of the formulations prepared from crude benzene hexachloride was reported to be as follows: (1) A 5 per cent dust containing 0.5 per cent of the gamma isomer, and (2) a 10 per cent dust containing 1.0 per cent of the gamma isomer. The 10 per cent dust formulation was also used as a water wettable powder.

CAGE TESTS.—These tests involved the application of sprays and dusts to entire single trees and also the placing of wire-screen cages, each containing 25 adult plum curculios, over limbs bearing fruit and foliage. At one end of each cage was a cloth sleeve, which was tied to a limb to hold the cage in place. Sprays were applied with a double-acting hand spray pump at 180 to 200 pounds pressure, and dusts were applied with a knapsack hand duster of bellows type. Three series of cage tests were carried out. The first series was started April 9, using overwintered curculios jarred from unsprayed trees that day; the second on May 27, using first-generation adult curculios that emerged from the soil on May 26 or 27 and had done no feeding; and the third on July 12, using first-generation adults that emerged during the period May 25 to June 1 and had been maintained in the insectary on untreated peach fruit and foliage. The treatments used and results are given in table 1. The results from the second series of cage tests are believed to have been affected by a beating rain, amounting to 2.69 inches, that fell 5 days after the tests were started.

Although the results of the cage tests with benzene hexachloride were not spectacular, they indicated that this material has promise as an insecticide for the control of the plum curculio on peach. A number of dead larvae about 3 days old were found in peaches 2 weeks after they were sprayed with the 3.79 per cent gamma benzene hexachloride at the rate of 6 pounds per 100 gallons of spray. There were also many empty larval channels in the fruit at that time, indicating that the larvae had died and decomposed. The indication is that the material will have to be used at the rate of at least 1 pound of the technical material (containing at least 10 per cent of the gamma isomer) per 100 gallons of spray. Lower dosages were less effective than the usual strength of lead arsenate. In these tests white-oil emulsion did not improve the effectiveness of the material sufficiently to justify the added cost; the crude benzene hexachloride appeared to be somewhat more effective than the technical grade; and, in general, the benzene hexachloride dusts were not so effective as the sprays. When used on foliage alone (after harvest), benzene hexachloride appeared to repel the curculios the first week, killed them the second or third week, and had very little effect after that time. Results of tests conducted before harvest showed a similar trend.

SINGLE-TREE TESTS.—During the period June 27 to July 15 the peaches were harvested from the trees used for the cage tests started on April 9 and May 27, and the fruits were cut open to deter-

[1] Acknowledgement is made to Julius P. Hollon who assisted in all of the experiments reported in this paper.

Table 1.—Mortality of plum curculio adults on peach trees at Fort Valley, Ga., after spray and dust applications of benzene hexachloride, in comparison with lead arsenate sprays, 1946.

Treatment	Date Test Was Started	Per Cent Mortality after— 7 Days	14 Days	21 Days	28 Days	35 Days	42 Days
Sprays (Amount per 100 gallons):							
Benzene hexachloride (technical) wettable powder, 3.79 per cent gamma isomer:							
12 oz.	April 9	8	12	12	16	16	16
24 oz.	April 9	16	36	36	44	60	60
3 lbs.	April 9	79	88	92	92	92	92
	May 27[1]	22	96	96	96	96	—
	July 12	0	24	28	32	40	—
3 lbs. plus 1 quart summer-oil emulsion	April 9	88	96	96	96	96	96
	May 27[1]	28	28	36	36	48	—
	July 12	4	68	72	72	72	—
6 lbs.	April 9	96	100	—	—	—	—
	May 27[1]	60	64	64	64	72	—
	July 12	4	48	48	48	52	—
20 lbs. Benzene hexachloride (crude) 1.0 per cent gamma isomer	May 27[1]	28	80	80	84	84	—
	July 12	0	100	—	—	—	—
2 lbs. Lead arsenate plus 2 lbs. zinc sulfate and 8 lbs. hydrated lime	April 9	8	48	96	100	—	—
	May 27[1]	20	48	48	48	72	—
	July 12	0	48	56	68	80	—
Check No. 1 (untreated)	April 9	0	0	0	4	8	16
	May 27	4	8	8	8	8	—
	July 12	0	8	8	8	16	—
Dusts (per cent gamma isomer benzene hexachloride):							
0.575 % Technical material	April 9	12	28	72	100	—	—
	May 27	16	16	16	20	24	—
	July 12	4	75	75	75	75	—
1.15 % Technical material	April 9	24	24	24	24	24	24
	May 27	40	40	40	44	48	—
	July 12	0	12	12	16	24	—
0.5 % Crude material	May 27	0	4	28	28	28	—
	July 12	4	76	76	76	76	—
1.0 % Crude material	May 27	38	46	50	58	58	—
	July 12	0	100	—	—	—	—
Check No. 2 (untreated)	April 9	8	12	12	23	23	23
	May 27	12	12	12	16	16	—
	July 12	4	96[2]	100[2]	—	—	—

[1] Wettable sulfur, 6 pounds, added to 100 gallons of spray.
[2] Contaminated when dusting nearby tree with benzene hexachloride.

mine the percentage infested with curculios. The results are given in table 2.

While the single-tree tests were conducted primarily to determine the phytocidal effect of benzene hexachloride on peach fruit and foliage, and were too small to give a fair measure of its insecticidal efficiency, the results indicate its value for plum curculio control. This is especially true because these tests were conducted against a heavy infestation on the Belle of Georgia variety, which is very susceptible to curculio attack. More than half the fruits on the check trees were infested. The results indicated that, under the above conditions, two applications of 6 pounds of the 3.79 per cent gamma benzene hexachloride wettable

Table 2.—Control of the plum curculio on peaches at Fort Valley, Ga., in single-tree tests with benzene hexachloride sprays and dusts, in comparison with a lead arsenate spray, 1946.

TREATMENT	APPLICATIONS	FRUITS INFESTED
	Number	*Per Cent*
Sprays (amount per 100 gallons):		
Benzene hexachloride (technical) wettable powder, 3.79 per cent gamma isomer:		
12 oz.	1	33.3
24 oz.	1	38.0
3 lbs.	2	36.1
3 lbs. plus summer-oil emulsion 1 quart	2	7.2
6 lbs.	2	7.5
20 lbs. Benzene hexachloride (crude), 1 per cent gamma isomer	1	0.0[1]
2 lbs. Lead arsenate, plus 2 lbs. zinc sulfate and 8 lbs. hydrated lime	2	32.8
Check No. 1 (untreated)	—	54.8
Dusts (per cent gamma isomer benzene hexachloride):		
0.575 % Technical material	2	16.7[1]
1.15 % Technical material	2	57.7
1 % Crude material	1	42.9
Check No. 2 (untreated)	—	51.1

[1] Fruit crop considerably smaller than that on other trees in experiment.

Table 3.—Control of the plum curculio on peaches at Fort Valley, Ga., with benzene hexachloride (wettable powder), in comparison with a lead arsenate spray, 1946.

TREATMENT (MATERIALS AND AMOUNT PER 100 GALLONS)	INFESTED FRUITS AT HARVEST TIME
	Per Cent
Lead arsenate, 2 lbs. at petal-fall, shuck-off and 4 weeks prior to harvest	38.7
Benzene hexachloride (3.79 per cent gamma isomer) 1 lb. at petal-fall and 3 lbs. at shuck-off and 4 weeks prior to harvest	34.9
Benzene hexachloride (3.79 per cent gamma isomer) 1 lb. at petal-fall and 3 lbs. at shuck-off; 2 lbs. lead arsenate 4 weeks prior to harvest	44.9
Check (untreated)	62.0

powder alone, or 3 pounds in combination with 1 quart of a summer-oil emulsion per 100 gallons of spray, may be very effective against the plum curculio. However, both these treatments affected the flavor of the fruit.

ORCHARD TESTS.—Benzene hexachloride was used on two small plots in an experiment conducted for control of the plum curculio in a commercial peach orchard in 1946. The wettable powder reported to contain 31.6 per cent of technical benzene hexachloride and 3.79 per cent of the gamma isomer was used, in comparison with lead arsenate. Applications were made at petal-fall, shuck-off (about 10 days after petal-fall), and 4 weeks prior to harvest. Wettable sulfur, 6 pounds per 100 gallons, was included in all treatments applied at shuck-off and 4 weeks prior to harvest. Zinc sulfate, 2 pounds, and hydrated lime, 8 pounds, were used with lead arsenate in all applications. The fruit was harvested during the period June 28 to July 8, and each peach was cut open to determine the percentage of fruits infested with the curculio. The results are given in table 3.

About half the trees died from winter injury during the period between petal-fall and shuck-off, and others between shuck-off and harvest time. The infestation (62 per cent) in the check was considered very heavy, and was indicative of the infestation in the experimental orchard. Undoubtedly this was due in some measure to the concentration of adult curculios on the few live trees that remained in a number of the replicates that suffered heavy mortality from winter injury. Because this experiment was conducted under such abnormal conditions, the results may not indicate the comparative value of the treatments under more normal conditions, but they do afford a preliminary evaluation.

Benzene hexachloride was slightly more effective than the standard lead arsenate treatment under the conditions of these tests. This was true, despite the fact that only 1 pound of the wettable powder was used in the petal-fall application, whereas the cage tests indicated that at least 3 pounds were necessary for satisfactory results.

EFFECT OF BENZENE HEXACHLORIDE ON FRUIT, FOLIAGE, AND TREES.—In the tests conducted in 1946 no injury resulted to fruit from two applications of 6 pounds or less of the 31.6 per cent water-dispersible benzene hexachloride powder per

100 gallons of spray, and none could be discerned on peach foliage, buds, budwood, or any other part of the trees from four similar applications on April 9, May 27, July 12, and September 5. Two applications of dusts containing 10 per cent or less of benzene hexachloride caused no injury to fruit, and four applications caused no injury to foliage or trees. Benzene hexachloride as used in the orchard tests (Table 3) did not affect the flavor of the fruit, and as used in other tests did not noticeably affect fruit flavor when used in two applications, the second a month prior to harvest, with not more than 3 pounds of the 31.6 per cent water-dispersible benzene hexachloride powder per 100 gallons of spray. However, the flavor of the fruit was adversely affected when two applications, the latest a month before harvest, of 3 pounds of the above water-dispersible powder were made in combination with 1 quart of a summer-oil emulsion, or when 6 pounds of this material was used alone per 100 gallons of spray. None of the benzene hexachloride dusts used affected the flavor of the fruit so far as could be detected; however, they were less effective than the sprays.

TREATING PEACH DROPS.—A preliminary experiment was conducted in 1946 to determine the value in plum curculio control of treating peach drops with benzene hexachloride. On April 24, 2 quarts of peach drops collected that morning were sprayed with 6 pounds of the 31.6 per cent water-dispersible benzene hexachloride powder to 100 gallons of water, and then placed in a wire tray for emergence of larvae. The drops were rolled over as they were being sprayed, to cover all sides of each. A similar quantity (2 quarts) of drops collected on the morning of April 24 was left unsprayed as a check and placed in another wire tray. Larvae began to emerge the next day, and for 6 days after treatment about the same number emerged from each tray. After 6 days no larvae emerged from the treated drops except 1 on May 3 and 1 on May 14. whereas larvae continued to emerge from the untreated drops until May 27. A total of 65 larvae emerged from the untreated drops, as compared with 28 from the treated ones. This preliminary experiment indicates that benzene hexachloride is a promising insecticide for treating peach drops to prevent the maturing of plum curculio larvae. Apparently, several days are required for sufficient penetration of the material to prevent the emergence of maturing larvae.

The larvae that emerged from the treated and untreated drops were placed in separate containers with soil for records of their subsequent development. Adults began to emerge from both containers on May 31. The total number of adult plum curculios that emerged from the 65 larvae reared in the untreated drops was 29, or 44.6 per cent, and the number that emerged from the 28 larvae reared in the treated drops was 10, or 35.7 per cent. These data indicate that the benzene hexachloride may also have had some effect on the larvae that managed to emerge from the treated drops.

SOIL TREATMENT.—In laboratory experiments benzene hexachloride at the rate of 3 pounds of the 31.6 per cent water-dispersible powder to 100 gallons of water was not very effective as a ground spray to prevent the development of the plum curculio in the soil. When used at the rate of 1 gallon per square yard of soil the day before plum curculio larvae entered it, 10.1 per cent of the larvae reached the adult stage and emerged. The adults that emerged from the soil sprayed with the benzene hexachloride were not affected by the treatment.

SUMMARY.—The results of cage, single-tree, and orchard tests indicate that benzene hexachloride has promise as an insecticide to control the plum curculio on peach. These results indicate that about 1 pound of benzene hexachloride containing at least 10 per cent of the gamma isomer is needed per 100 gallons of spray for effective control, that the material is more effective used as a spray than as a dust, that concentrations containing 6 pounds or less of a 31.6 per cent water-dispersible powder per 100 gallons of spray will not injure peach fruit, foliage, buds, budwood, or other parts of the tree, and that the material may affect fruit flavor adversely if used in sufficient concentration too close to the harvest period. In preliminary experiments the material also showed promise for treating peach drops to prevent the emergence and subsequent development of plum curculio larvae.—1-23-47.

The Use of DDT on Citrus Trees in Florida

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In the spring of 1946, Boyce & Ewart (1946) suggested the use of DDT for the control of thrips and citricola scale in the California citrus area, but cautioned, "There is uncertainty regarding the possible detrimental effect of DDT treatments on parasites and predators of the cottony cushion scale, soft brown scale, yellow scale, and aphids. It is possible that these insect pests may increase in numbers where extensive treatments of DDT are made." Seven months later, in September, it was reported[1] that cottony cushion scale infestations on citrus were showing disturbing increases following the use of DDT for the control of thrips and scale. In addition to this undesirable result Lindgren (1946) and Cressman & Broadbent (1946) had previously reported citrus red mite, *Paratetranychus citri* McG. (this mite is commonly referred to as the purple mite in Florida), increases following the experimental use of DDT for the control of purple scale and citricola scale.

This account is a preliminary report of the use of DDT on citrus trees in Florida. Here, the only recommendations concerning DDT applications on citrus has been for the control of the little fire ant, *Wasmannia auropunctata* Roger. Osburn (1945) reported satisfactory control of this pest when he sprayed a DDT-fuel oil emulsion on the trunks and heavy limbs of infested trees.

DDT was first used by the Citrus Experiment Station in central Florida in the summer of 1944. Oil was saturated with technical DDT and applied as 1.0 per cent and 1.4 per cent oil emulsions to test the possibilities of the addition of DDT for the control of purple scale. Observations made through the succeeding months failed to show either beneficial or detrimental effects which could be attributed to the use of DDT at the concentrations used.

In 1945, DDT was tried more extensively. Parts of four different groves in the central portion of the state were sprayed with solutions containing DDT. As each of the groves represents a different situation, the treatments will be discussed separately.

Grove A consisted of Valencia orange trees which were uniformly infested with Florida red scale, *Chrysomphalus aonidum* L. The DDT was applied as a wettable material (1 lb. DDT per 100 gal.), in an oil emulsion in July. No initial or long term effects of DDT were noted.

The trees in Grove B were seedy grapefruit. Both Florida red scale and purple scale were present in fair numbers. Wettable DDT (1 lb. DDT per 100 gal.) was applied in an oil emulsion in June on part of the grove. The addition of DDT did not appear to influence the initial scale kill. However, after 10 months there was a very noticeable increase in the red scale populations on all the trees sprayed with DDT. The grove was routinely sprayed with arsenic and oil on May 15, 1946. A 25 per cent wettable DDT mixture (1.25 lbs. DDT per 100 gal.) was added to one spray tank and this mixture was used on 16 trees, all of which had received DDT in 1945. Initial scale mortality was high throughout the grove. On June 25, 1946, checks were made to determine the densities of the Florida red scale parasite, *Pseudohomalopoda prima* Gir. This parasite is readily found as a late stage larva or as a pupa in third stage red scale females. In addition to actual parasites, emergence holes are easily recognized and these are included in the parasite counts discussed below. The results of the count are shown in table 1. It will be noted that there is a marked difference in the parasite densities on the different treatments. In spite of the fact that an additional oil spray had been applied throughout the grove in July; in October, 5 months after the DDT applications, the scale population on the trees sprayed with DDT and oil in April had reached an average of about 200 per leaf, according to randomized leaf counts on foliage within reach of the ground. At the same time, not more than 1 per leaf were found on the oil treated trees. Parasite counts taken in October showed trends similar to those observed in June. In addition to *Pseudohomalapoda prima* Gir., *Prospaltella aurantii* How. was included in the count. This parasite is found

emerging from late second stage scale. It has been recognized by the authors only as a very late stage larva, as a pupa, and by emergence holes in late second or very early third stage Florida red scale. The incidence of *P. prima* was more than 30 times higher in third stage scale on those trees which did not receive the April DDT application. Similarly, *P. aurantii* was 8 times more common in second stage scale on the same trees.

At the time that the above parasite counts were made in Grove B, a check was also made for citrus red mites. Infestations were significantly higher on the DDT sprayed trees. It should be noted that no DDT had been sprayed on the trees since May and another spray of oil (an efficient acaricide) had been applied in July. Thus, if DDT were the causative agent, the apparent effects were long range and were not prevented by the inclusion of oil in the initial spray or by its subsequent application. This aspect must be considered by workers attempting to counteract the adverse effects of DDT on parasites and predators by the addition of an acaricide at the time of DDT application.

Table 1.—Density of *Pseudohomalapoda prima* Gir. in third stage Florida red scale following different spray treatments in 1945 and 1946.

Treatment		Parasite Counts June 25, 1946	
June 1945	May 1946	Average Evidences of Parasites per 100 3rd Stage Live Scale[1]	Live Parasites per 100 Live Scale
Oil	Oil	163	35
Oil-DDT	Oil	15	8
Oil-DDT	Oil-DDT	7	0

[1] Includes live parasites, dead parasites, and emergence holes.

In Grove C, DDT was applied as a wettable material (1 lb. DDT per 100 gal.) in oil emulsions for the experimental control of snow scale, *Chionaspis citri* Comst. The trees were mainly old seedlings and the trunks and large limbs possessed fairly heavy populations of snow scale. Therefore, both the wood and the foliage were thoroughly sprayed. Two sprays were applied; the first one in May and the second in July. The treatments which included DDT were not significantly better for snow scale control than the straight oil sprays. Although there was no noticeable red scale buildup by April of the following year, 2 months later, in June, the DDT treated trees could be easily separated from the oil sprayed ones by the presence of heavy red scale populations on the former. At that time, scale counts showed from 2 to 9 times as many scale on the DDT sprayed trees as on either the oil sprayed ones or on the untreated checks. No measurable differences were found in parasite densities at that time and earlier counts had not been made.

In Grove D a wettable DDT was applied with an oil emulsion (0.75 to 1.0 lb. DDT per 100 gal.) and also with sulfur (two applications, 0.1 to 0.5 lb. DDT per 100 gal.) in August, 1945. By January 1946 there were unusual increases of red scale on all plots except those receiving a straight oil or those with DDT as low as 0.1 lb. DDT per 100 gallons of spray solution. The highest populations were attained on the sulphur-DDT sprayed trees. The difference in scale density was apparently due to a considerable extent to the differential in initial kill effected by the oil. In the spring of 1946, another series of experimental plots was arranged in the same block and these were sprayed April 25, 1946. Wettable DDT was included at the rates of 1 and 2 lbs. of a 50 per cent material in 100 gallons of an oil emulsion. Initial kills appeared to be slightly better where DDT was applied, but the difference was not considered to be significant.

Osburn (1945) reported that the twice-stabbed lady beetle, *Chilocoris stigma* Say was killed in considerable numbers where DDT was used for the control of the little fire ant. Following the DDT sprays in Grove D, counts were made for dead lady beetles at the base of all trees. The results are shown in table 2. DDT not only killed more beetles initially, but its use resulted in the virtual elimination of the species from DDT sprayed trees for a period of 6 weeks or longer. The beetles continued to be plentiful on both the oil sprayed and the unsprayed check plots. The parasite counts of *Pseudohomalapoda prima* Gir. made in June are also shown in table 2. As in Grove B, parasite incidence was markedly reduced on the

DDT sprayed plots. There, red scale populations increased rapidly and were worse on the trees receiving the greater amounts of DDT. In 10 of the 12 plots it was necessary to apply a second oil spray in July. By that time, according to randomized leaf counts, red scale populations had reached a level which varied between 5 and 250 scales per leaf. By comparison, scale populations on all plots which did not receive DDT were reduced almost to zero.

Table 2.—Effect of different sprays on twice-stabbed lady beetles and on Florida red scale parasite, *Pseudohomalapoda prima* Gir.

Treatment	Avg. Evidences of Parasites per 100 3rd Stage Live Scale[1]	Live Parasites per 100 Live Scale	Per Cent of Parasites Dead	Dead Lady Beetles per Tree after Spray[2]
None	10	10.3	3	1
Oil	13	7.3	13	17
Oil 0.5 lb. DDT	3	0.6	17	62
Oil 1 lb. DDT	5	0.2	45	61

[1] Parasite counts made on June 10, 1946.
[2] Lady beetle counts made on May 7, 1946.

It is of interest to note that on June 26 when citrus rust mite, *Phyllocoptruta oleivora* Ashm., and citrus mealy bug, *Pseudococcus citri* McG., counts were made that both pests were present in significantly higher numbers on the DDT-sprayed trees than on the oil sprayed ones or on the unsprayed checks. Unfortunately, citrus red mite counts were not made in this block.

Thus, it may be concluded that the use of DDT on citrus trees in Florida is likely to create a situation favorable to serious population increases of Florida red scale. These increases appear to result from the almost complete elimination of insects which are parasitic or predaceous upon the scale. In addition to Florida red scale, significantly higher populations of citrus mealy bug, citrus rust mite, and citrus red mite have been noted on trees receiving DDT applications. In view of this situation, it is believed by the authors that DDT should not be used on the foliage of citrus trees in Florida. It appears possible that where ant control is necessary DDT may be used safely as a dust barrier about the bases of young trees or as a spray on the large limbs and trunks. In the latter instance extreme care should be taken to minimize the deposition of DDT on the foliage of the treated trees.

SUMMARY AND CONCLUSIONS.—Where DDT was used in Florida in 1944, no detrimental results were noted. In 1945 and 1946, there were serious outbreaks of Florida red scale following five of the six applications. Also higher populations of citrus rust mites, citrus mealy bugs, and citrus red mites were noted on DDT sprayed trees. It is therefore concluded that DDT should not be used on citrus foliage in Florida. It is suggested that it might be used with safety for ant control if applied as a dust barrier about the base of young trees or if applied only to heavy limbs and trunks of more mature trees.—12-26-46.

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Effects of Chlorinated Hydrocarbons and Sabadilla on Insects and Plants

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Three chlorinated hydrocarbons, DDT, benzene hexachloride ($C_6H_6Cl_6$) and chlordane ($C_{10}H_6Cl_8$), and sabadilla were compared on six species of insects and on four types of plants. The materials were used as both sprays and dusts and were tested in the laboratory and in the field. The work was done in north central Oklahoma during 1946. The insect species and the plants included in the tests were:

Squash bug, *Anasa tristis* (Deq.)	Cucurbits
Spotted cucumber beetle, *Diabrotica duodecimpunctata* (F).	Cucurbits
Striped cucumber beetle, *D. vittata* (F.)	Cucurbits
Hawthorn lace bug, *Corythuca cydoniae* (Fitch)	*Pyracantha*
Chinch bug, *Blissus leucopterus* (Say)	Sorghums
Garden webworm, *Loxostege similalis* (Guen.)	Alfalfa

MATERIALS AND METHODS.—DDT dusts were made by diluting a 50-per cent dust[1] with talc, and DDT sprays were prepared from a 50 per cent commercial preparation.[2] Dusts containing chlordane[3] (agricultural grade) were prepared by impregnating a solution of the material in acetone on talc. Subsequent mixing and storage in cloth sacks resulted in evaporation of the solvent. Sprays were obtained by diluting with water a mixture consisting of 1 part chlordane, 1 part emulsifier[4] and 2 parts xylene. Dusts and sprays of benzene hexachloride were made by using a wettable powder[5] consisting of benzene hexachloride (10 per cent gamma isomer) 50 per cent, and inert ingredients, 50 per cent. Thus, in all such mixtures the gamma isomer content was 10 per cent of the benzene hexachloride content. Talc and water were used as diluents in dusts and sprays, respectively. Sabadilla dusts consisted of varying proportions of talc and a 50 per cent sabadilla concentrate.[6]

With the exception of tests made on the garden webworm, all dusts were applied with rotary hand dusters. In the tests on garden webworms, a power duster[7] was used. In spraying tests, sprays were applied by means of 3-gallon compressed-air sprayers except in the case of hawthorn lace bug tests in which case they were applied with a power sprayer[8]. In laboratory tests made on squash bugs and cucumber beetles, insects were placed in a quart jar and subjected to 50 milligrams of dust introduced with a bellows-type dust gun. The jar was inclined at an angle of approximately 45° and rotated a fixed numder of times, thus resulting in thorough dusting of all insects. The insects were removed and jarred on screen wire to remove excess dust and were then placed in clean containers and supplied with squash fruit for food. In field-cage tests plants were dusted by the method used in field-plot tests after which clean insects were confined on them in sleeve-type screen wire cages.

SQUASH BUG.—Dusts containing DDT, benzene hexachloride, chlordane, and sabadilla were compared in 1946 against the squash bug in laboratory, field-cage and field-plot tests. Table 1 shows the effects of two concentrations of each of these materials on adult bugs in a laboratory test. Data are based on a minimum of four replicates of 10 bugs each made during a period when the maximum temperature was 80° F., the minimum was 70° F., and the mean 77.8° F.

DDT and benzene hexachloride were compared with sabadilla in a field-plot test that included three varieties of squash planted May 2. The data given in Table 2 show plant development and yield expressed as percentages of the sabadilla plots which were used as standard checks.

The same materials and chlordane were included in a field-cage test that was replicated three times. At the end of 120 hours, the per cent mortality obtained for each material was as follows: DDT 5 per cent, 95.9; benzene hexachloride 5 per cent, 84.8; Chlordane 5 per cent, 80.6; sabadilla 10 per cent, 83.2; talc (check), none.

A second field-plot test, small in scope, was made on sugar pumpkins planted July 10. Each material was applied to a single plot containing six plants. When treatment was begun all plots were uniformly infested with heavy populations

[1] *Gesarol V-D50.*
[2] *Gesarol AK50.*
[3] *Velsicol 1068.*
[4] *Triton X-100.*
[5] E. I. du Pont de Nemours and Company.
[6] Supplied by John Powell and Co., Inc.
[7] Root Model ×8.
[8] John Bean Model 4-e.

Table 1.—Field plot tests on sugar pumpkins.

MATERIALS	DATE OF APPLICATIONS	TOTAL OUNCES OF DUST	AVERAGE NO. OF FRUITS	AVERAGE POUNDS OF FRUIT
DDT 5 per cent	Aug. 21, Sept. 17	2	13.8	36.8
Benzene hexachloride 5 per cent	Aug. 21, Sept. 17	2	13.7	38.3
Chlordane 5 per cent	Aug. 21, Sept. 17	2	12.0	37.1
Sabadilla 5 per cent[1]	Aug. 21, Aug. 25			
Sabadilla 10 per cent	Sept. 5, Sept. 17	4	12.2	32.3

[1] The sabadilla plot received two applications of 5 per cent dust followed by two applications of 10 per cent dust.

of squash bugs and cucumber beetles. The 42-day old plants were beginning to set fruit and were 6 to 8 feet in diameter. The amount of dust used and the yield are given in table 1 on a per plant basis.

In all tests 5 per cent benzene hexachloride and 10 per cent sabadilla were the most rapid in affecting squash bugs followed closely by chlordane (Table 2). DDT 5 per cent dust was significantly slower in action than these materials. Under the conditions of the laboratory test, decreasing the concentration to 2.5 per cent did not reduce the effectiveness of benzene hexachloride or chlordane appreciably. However, when DDT and sabadilla concentrations were lowered to 2.5 and 5.0 per cent, respectively, the effectiveness was greatly lessened. Data obtained in field tests showed that the period of protection resulting from the use of sabadilla was less than that obtained by using the other materials. By September 13 (Table 3), there were from 5 to 29 per cent more plants alive in these plots than in sabadilla plots. In the experiment on sugar pumpkins, four applications of sabadilla did not give as good protection as that afforded by 2 treatments of benzene hexachloride, DDT, or chlordane. All tests indicated that 5 per cent sabadilla dust is not adequate for control of squash bugs. Had 10 per cent sabadilla been used throughout in field tests the protection and yield for these plots would no doubt have been better. The results are in general agreement with those obtained in 1945 tests (Walton 1946) and indicate that effective control can be obtained with 10 per cent sabadilla and with 5 per cent dusts of the other materials.

The data on plant development given in table 3 show that all three varieties of squash were injured to some extent by both DDT and benzene hexachloride. The first treatment was made on May 17 when the plants were only a few days old and the data indicate that most of the injury resulted from this application. This is in general agreement with the effects of DDT on Acorn squash reported by Bruce & Tauber (1945). Harmful effects were generally more pronounced in the DDT plots. By July, 25 nearly all plots showed partial recovery from stunting and retardation of fruiting, and by September 13 yields from these compared favorably with those of sabadilla plots. Yields obtained in the test on sugar pumpkins, where fruiting had begun before treatment was started, indicate that injury was negligible on plants that were well past the seedling stage.

CUCUMBER BEETLES.—The four materials used in squash bug tests were also compared in laboratory and field-plot tests on cucumber beetles. The results are given in table 4. Data for the field-plot test were taken from sugar pumpkin plots from which records were presented

Table 2.—Per cent knockdown and mortality in a laboratory test on adult squash bugs.[1]

MATERIALS	HOURS AFTER TREATMENT								
	0.5	2	6	24		48		120	
	Knockdown[2]	Knockdown	Knockdown	Knockdown	Mortality	Knockdown	Mortality	Knockdown	Mortality
DDT 5 per cent	0.0	0.0	3.3	42.8	15.0	65.0	55.0	88.9	88.9
DDT 2.5 per cent	0.0	0.0	0.0	15.0	0.0	30.0	20.0	65.0	65.0
Benzene hexachloride 5 per cent	1.7	64.4	88.9	94.4	69.4	96.7	93.3	96.7	96.7
Benzehe hexachloride 2.5 per cent	0.0	65.0	85.0	90.0	50.0	95.0	75.0	90.0	90.0
Sabadilla 10 per cent	35.6	70.6	91.7	100.0	45.0	100.0	84.0	100.0	100.0
Sabadilla 5 per cent	0.0	10.0	20.0	45.0	0.0	50.0	25.0	50.0	50.0
Chlordane 5 per cent	1.7	6.7	33.9	96.7	35.8	100.0	85.7	100.0	100.0
Chlordane 2.5 per cent	0.0	0.0	0.0	90.0	20.0	95.0	75.0	100.0	100.0
Talc (Check)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.3

[1] Based on a minimum of 4 replicates of 10 bugs each.
[2] Bugs were counted as knocked-down if they were unable to regain their feet when placed on their backs.

Table 3.—Plant development and yield ratings obtained in squash plots treated with DDT and benzene hexachloride when sabadilla-treated plots used as standard checks, were assigned arbitrary ratings of 100.

Date and Plant Development	Materials					
	DDT			Benzene Hexachloride		
	White Bush	Yellow Crook Neck	Acorn	White Bush	Yellow Crook Neck	Acorn
June 20:						
Average Plant Size	69.6	93.1	56.0	111.2	88.4	78.4
Fruit Set Per Plant	17.5	64.3	17.1	83.3	42.6	32.6
July 25:						
Plants Alive	101.7	101.2	102.6	101.9	100.6	102.4
Accumulated Yield	76.5	57.8	96.4	103.8	82.2	78.9
September 13						
Plants Alive	121.1	104.0	129.1	123.7	105.5	125.1
Total Yield	93.1	73.8	106.0	107.6	85.9	90.0

Miscellaneous Data

Number replicates = 3 Number plants per plot = 16

Date of Applications:	May 17	June 18	July 4	Aug. 27
Per cent conc. of DDT and benzene hexachloride	5	5	10	5
Per cent conc. of Sabadilla	5	5	10	10

Weight of dust received per plant in 4 applications = 2.5 ounces.

Per cent of plants in sabadilla plots alive on: June 20 = 89.3 July 25 = 85.7 September 13 = 73.1

in the preceding section on squash bugs.

Although 5 per cent dusts of benzene hexachloride, DDT, and chlordane were approximately equal in total killing effects certain differences can be noticed in the results. Benzene hexachloride caused 100 per cent knockdown in 15 minutes as compared with 1 hour for the two others. However, 100 per cent kills were obtained in 6.5 and 7.5 hours with the latter materials, respectively, while 9 hours were required by benzene hexachloride. The quick knockdown effects of benzene hexachloride are shown in the counts of dead beetles found in plots. Low counts in DDT and chlordane plots, coupled with the fact that numerous dead beetles were found in vegetation adjacent to these plots, indicated that a high percentage of the poisoned beetles moved from the plots before dying. Sweeping records showed effective control was obtained with each of the three materials during the time from August 23 to September 18. While no sweeping was done after this time, fruit injury data taken on October 30 indicated that the protection was excellent through the remainder of the growing season. Five per cent sabadilla dust was inferior to other materials. Sabadilla 10 per cent dust was considerably better than the lower concentration but was significantly less effective than either benzene hexachloride, DDT, or chlordane.

On the basis of present information, recommendation for the use of DDT and benzene hexachloride on the tested varieties of squash and pumpkin must be made with certain reservations. Under Oklahoma conditions, cucurbits in the seedling stage are very often attacked by cucumber beetles but seldom are injured by squash bugs. Considering this fact and also the risk of injury by the insecticides it appears that these materials should not be recommended for use on young plants. It would seem advisable to use cryolite or a strong sabadilla concentration to control cucumber beetles early in the season, switching to one of the chlorinated hydrocarbons for squash bugs after plants begin to fruit, thus securing maximum protection from both of these pests.

HAWTHORN LACE BUG.—During July, the previously mentioned materials and two other insecticides were applied at various concentrations to *Pyracantha* shrubs to control the hawthorn lace bug. The shrubs varied in size, averaging sbout 6 feet tall and 7 to 8 feet in diameter. Infestations and injury varied greatly between plots, some shrubs suffering little

Table 4.—Results of tests on cucumber beetles.

LABORATORY TEST ON *Diabrotica duodecimpunctata*[1]

Materials	Time required to obtain— 100 Per Cent Knockdown[2]	100 Per Cent Mortality
DDT 5 per cent	1 hour	6.5 hours
Benzene hexachloride 5 per cent	15 minutes	9 hours
Chlordane 5 per cent	1 hour	7.5 hours
Sabadilla 5 per cent	35.7% in 24 hours	54.6% in 42 hours
Talc		0.0% in 42 hours

FIELD-PLOT TEST ON SUGAR PUMPKINS INFESTED WITH A MIXED POPULATION OF *Diabrotica duodecimpunctata* AND *D. vittata*

Materials	Beetles Per 10 Sweeps at Treatment August 21[3]	Per Cent Reduction August 23	Dead Beetles Per Sq. Ft. Aug. 23	Per Cent Control Aug. 23 to Sept. 18[4]	Per cent Fruits Unmarketable Due to Beetle Injury
DDT 5 per cent	16.1	100.0	.3	97.6	0.0
Benzene hexachloride 5 per cent	14.9	98.0	7.2	91.9	0.0
Chlordane 5 per cent	15.3	100.0	2.1	94.8	1.5
Sabadilla 5 and 10 per cent	16.8	71.4	.2	81.7	15.1

[1] Based on 4 replicates of approximately 20 beetles each; temperature range 84° F. to 97° F.
[2] Beetles were counted as knock-down if they were unable to regain their feet when placed on their backs.
[3] Four series of 10 sweeps were made on each plot.
[4] Based on sweepings made at approximately weekly intervals.

while damage on others was very conspicuous, both leaves and berries being discolored and desiccated. In the latter cases, a considerable portion of the foliage was shed in late summer. Abnormally high temperature and low humidity apparently acted as a check on the lace bug infestation. During August, large numbers of newly hatched nymphs disappeared in check plots where shrubs were exposed to the sun. Shrubs that escaped the afternoon sun, because of being located on the east sides of the buildings, had infestations significantly higher than those not thus protected. Furthermore, the population on the east side of such exposed shrubs was generally greater than that on the west side.

Population records were obtained by counting the number of bugs on the outer foot of 10 branches selected at random on each shrub. Randomization was modified in late August by making all counts on the east side of the shrubs. Each material was applied to three plots, a plot consisting of a single shrub. All plots were treated one time. Sabadilla dust was applied by means of a hand duster at a rate of about 2 ounces of dust per shrub.

Table 5 shows the effects of the various concentraations of the different materials on the lace bug populations. No injury to the plants by insecticides was observed in any plot. Excellent control was obtained with very low concentrations of DDT, benzene hexachloride, and chlordane. Complete control for a 60-day period resulted from the use of the higher concentrations of the three materials in Test No. 1. At the lower concentrations the order of effectiveness was: (1) DDT (2) chlordane and (3) benzene hexachloride. It will be noted that the gamma isomer content of the benzene hexachloride sprays was only 10 per cent that of the concentration of the DDT and the chlordane sprays with which they were compared. Sabadilla 10 per cent dust was very toxic to the lace bug but the inadequate coverage given resulted in control below that of the three materials discussed above. In considering the factor of coverage, it is probable that if the above sprays had been applied with compressed-air hand sprayers instead of by a power sprayer with high pressure, the control would have been less effective. The nicotine sulphate-summer oil and thiocyanate[1]

[1] In cooperation with R. G. Dahms, Assistant Entomologist, Bureau of Entomology, and Plant Quarantine and Oklahoma Agricultural Experiment Station, and with Frank Davies, Associate Agronomist, Oklahoma Agri. Expt. Sta.

Table 5.—Results of field tests on the hawthorn lace bug on *Pyracantha* shrubs.

MATERIALS[1]		TEST[2] NO.	AVERAGE NO. OF BUGS PER LIMB	PER CENT ALIVE ON 2ND DAY	AVERAGE PER CENT[3] INFESTATION
			Before Treatment	*After Treatment*	*For 60-Day Period*
DDT	1.0%	1	18.1	0.0	0.0
	.5%	2	11.6	0.0	0.5
	.12%	3	13.0	0.4	0.3
	.06%	4	17.2	0.9	0.4
Benzene hexachloride	1.0%	1	16.2	0.0	0.0
	.5%	2	18.7	0.6	3.7
	.12%	3	7.9	0.0	1.5
	.06%	4	13.5	5.8	11.4
Chlordane	1.0%	1	28.7	0.0	0.0
	.5%	2	6.6	0.4	0.1
	.12%	3	15.5	0.7	0.2
	.06%	4	9.4	0.6	2.8
Sabadilla Dust	10.0%	1	12.1	4.3	11.9
	10.0%	2	16.6	2.1	7.7
Nicotine sulphate plus Summer Oil[4]	.10% .25%	1	15.4	1.6	10.9
Nicotine sulphate Summer Oil	0.5% .12%	2	7.0	15.9	33.2
Nicotine sulphate Summer Oil	.025% .062%	3	11.4	22.5	25.7
Nicotine sulphate Summer Oil	.05% .12%	4	29.6	22.1	38.7
Lauryl thiocyanate[5]	.25%	1	20.9	4.1	25.5
	.12%	2	15.1	22.2	55.3
	.062%	3	6.7	13.8	25.8
	.12%	4	12.3	36.8	40.1
Water Only (Check)		1	14.7	92.4	97.1
		2	4.5	83.5	65.7
		3	12.1	113.9	86.2
		4	16.9	98.7	76.8

[1] All plots were treated once, each shrub receiving approximately 3 gallons of spray or 2 ounces of sabadilla dust.
[2] The dates of treatment application for Test Nos. 1, 2, 3, and 4 were July 11, 17, 19, and 20, respectively.
[3] Determined by averaging 4 counts made at intervals of approximately 2 weeks.
[4] *Superla* summer spray oil.
[5] *Loro.*

sprays at their highest concentrations gave good initial control but failed to prevent a subsequent increase in the population. Lower strengths of these materials were much less effective. The results of using water at a pressure of 250 pounds suggests that prolonged spraying with water to control the lace bug would not be practical. These results indicate that effective control of the lace bug can be obtained by thoroughly spraying shrubs with concentrations of either DDT, benzene hexachloride, or chlordane as low as 0.12 per cent.

CHINCH BUGS.—Barrier tests with sabadilla and DDT on chinch bugs in 1945 were reported by Walton (1945). In June 1946 DDT, benzene hexachloride, and sabadilla, in the form of 5 per cent dusts, were applied to 18 varieties of grain, syrup, and forage sorghums to protect against migrating chinch bugs. Beginning about June 7 and continuing until June 16, bugs migrated into the sorghum from a barley field bordering the south ends of the plots. At the time of first treatment, chinch bugs were abundant in the south third of each plot and some of the plants were already injured beyond recovery. Each variety was planted in 4-row plots 120 feet long and thinned to a hill of three or four plants every 28 inches. Three rows of each variety were dusted, a different insecticide being used on each row, while

Table 6.—Plant injury and yields in sorghum plots dusted for chinch bug control.

Varieties[1]	Plants Killed, Per Cent	Immature Plants, Per Cent	Forage per Acre, Tons
Sabadilla			
Sunrise Kafir	5.1	9.6	5.96
Sharon Kafir	7.6	6.4	4.04
Standard Kafir	17.8	28.9	3.94
Average	9.2	14.9	4.65
Average of 18 varieties	18.6	15.5	
Benzene Hexachloride			
Sunrise Kafir	11.1	8.7	6.59
Sharon Kafir	4.3	14.1	4.93
Standard Kafir	4.5	38.5	5.13
Average	7.1	20.4	5.55
Average of 18 varieties	12.1	16.9	
DDT			
Sunrise Kafir	8.2	10.5	6.43
Sharon Kafir	14.0	9.8	4.72
Standard Kafir	6.6	28.1	4.67
Average	9.9	16.1	5.27
Average of 18 varieties	18.3	15.9	
Check			
Sunrise Kafir	30.6	12.7	3.94
Sharon Kafir	22.7	7.8	3.42
Standard Kafir	43.4	28.1	2.49
Average	31.2	16.2	3.28
Average of 18 varieties	39.2	21.4	

[1] Based on four-row plots 120 feet long.

the fourth row was left untreated as a check. The dusts were deposited on and about the base of the plants using a minimum of air-blast, resulting in "sprinkling" rather than true dusting. Plots were treated twice, June 11 and 14, at approximately 20 pounds per acre. At this time, the plants were 4 to 8 inches tall.

The summarized data showing chinch bug injury are given in table 6. Due to experimental procedure necessary to carry out agronomic tests, for which the varieties were planted, forage weights for all treatments were obtained only for the three kafir varieties shown. It can be noted that, compared with the average of all 18 varieties, chinch bug injury to Sunrise and Sharon was low while damage to Standard was generally typical of the entire group. Benzene hexachloride gave the most effective protection. The average per cent of plants killed for the 18 varieties was: benzene hexachloride, 12.1; DDT, 18.3; sabadilla, 18.6; and untreated check 39.2. The only insecticidal injury observed was slight burning in benzene hexachloride plots.

GARDEN WEBWORM.[1]—In July, barrier and dusting tests were made against the late larval instars of the garden webworm in alfalfa.

The materials used in making barriers were: DDT, 10 and 50 per cent; benzene hexachloride, 10 and 100 per cent; sabadilla, 10 and 50 per cent; and creosote. Barriers 0.75 inch wide were constructed on tamped soil in the form of small rings. Approximately 30 worms were collected and placed in each ring. All worms crossed the barriers in 3 to 5 minutes, after which they were placed in clean containers and given fresh food. Counts of dead and living worms were made at the end of 31 hours.

In the dusting test, 5 per cent DDT, 5 per cent benzene hexachloride, 10 per cent sabadilla, and 5 per cent chlordane were compared with calcium arsenate. The dusts were applied at approximately 20 pounds per acre. Fourteen hours after treatment, worms were collected from each plot and supplied with food for an additional 28 hours. At the end of this period, counts of living and dead worms were made.

At the concentrations used most of the materials were ineffective in both tests. In the barrier test, the best results were obtained with chlordane, 5 per cent dust, and 50 per cent DDT, being 36.8 and 39.1 per cent control respectively. The per cent of control in dusted plots was as follows: DDT, 36.8; chlordane, 21.1; sabadilla, 20.9; benzene hexachloride, 10.5; and calcium arsenate, 9.2. The most promising material appeared to be chlordane particularly since it was tested at only a relatively low strength (5 per cent dust). It should be tested at higher concentrations.

SUMMARY.—DDT, benzene hexachloride, chlordane and sabadilla were tested against six species of insects and on four types of plants. Each of these was initially effective against the squash bug and the

[1] In cooperation with R. G. Dahms, Assistant Entomologist, Bureau of Entomology and Plant Quarantine and Oklahoma Agricultural Experiment Station.

hawthorn lace bug but the first three materials gave longer periods of protection than did sabadilla. The three chlorinated hydrocarbons were significantly more toxic to cucumber beetles than was sabadilla. Two applications of 5 per cent dusts of DDT, benzene hexachloride, and sabadilla controlled chinch bugs migrating into plots of young sorghums, with the first two materials giving better protection. None of the four insecticides was effective against the garden webworm in dusting and barrier tests.

Sorghum, alfalfa and *Pyracantha* shrubs sustained no important injury from being treated with either of the materials. White bush, Yellow Crook-neck, and Acorn varieties of squash were seriously retarded in development when treated at an early age with DDT and benzene hexachloride. Marked recovery was made by these plants during the remainder of the season. No injury to sugar pumpkins appeared in a test including all four materials in which dusting was begun when the plants were 42 days old.

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European Corn Borer Control on Canning Corn[1]

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Years of entomological endeavor have gone into the study of corn borer control on early market garden sweet corn by the use of insecticides. Protecting very early plantings of market garden corn from the first brood borer has become an accepted practice in many areas but the market grower is less apt to use insecticides to control second brood corn borers because the returns from the late crop are greatly reduced. The sweet corn canner is in a different position. His spring plantings are normally delayed until good growing conditions are assured and he uses sweet corn varieties of longer maturity than the market grower. These two factors decrease the possibility of having a serious first brood infestation. Once planting is started in May, successive plantings are made almost daily until late June. In Illinois, at least, these June plantings of canning corn are most attractive to second brood moths migrating from neighboring field corn which has become too mature to attract much egg laying. Therefore, the canner experiences moderate to heavy corn borer infestations in the principal part of his crop. Seldom are these second generation infestations as intense as those occurring on early market corn; nevertheless, any population over 3 to 4 borers per plant is hazardous to the canner because of the danger of contaminating the canned product.

To a limited extent, sweet corn canners have accepted and followed recommendations based upon studies involving the use of insecticides applied on market garden corn with ground dusting and spraying equipment. Because of the large acreages involved, however, ground equipment is not very popular with canners who tend to favor aerial dispersion of insecticides. To meet the demand for information, experiments were conducted in Illinois during 1945 and 1946 to determine the value of aerial applications of insecticides for corn borer control on canning corn. Some of the 1946 comparisons were made with a row crop duster mounted on a detasseling rig.

1945 TESTS.—The 1945 experiments in aerial dusting and spraying were conducted at Rochelle, Illinois, on corn grown by the California Packing Corporation. The borer population in north central Illinois was the highest to be found anywhere in the midwestern corn belt and afforded ample opportunities for studying this new approach to borer control.

Biplanes were used for distributing both dusts and sprays on strip plots 16 rows wide. Flight lines were 48 rows apart, allowing for buffered check plots between each of the treated plots. Tests were made only on second brood borer. This brood

[1] Richmond Program Paper.

[2] Entomologist, Ill. Natural History Survey & Ill. Agr. Expt. Sta.; Field Entomologist, Illinois Nat. Hist. Survey; and Assistant Entomologist, Ill. Nat. Hist. Survey, and Ext. Entomologist, Ill. Nat. Hist. Survey, respectively.

Table 1.—Evaluation of insecticidal treatments for corn borer control on canning corn, Rochelle, Illinois, 1945.

Formulation	Rate per Acre	Borers/Plant		Per Cent Reduction					Per Cent Increase	
		Check	Treated	Borers per Plant	Borers in Stalks	Borers per Ear	Tip Damage to Ears	Side Damage to Ears	Gross Yield	Cut Kernel Yield
0.67 lb. DDT/gal. *Velsicol AR 60-Superla 13*	2.25 gal.	20.9	2.3	89	98	70	59	70	17	32
5% DDT dust	40 lb.	12.6	2.0	80	96	66	43	89	17	22
5% DDT dust	20 lb.	20.7	3.2	85	91	58	44	71	18	28

Differences between treatments not significant.

was late in 1945 and the first treatments were not applied until September 2. Additional applications were made September 10 and 18. All tests were run in duplicate.

In taking the results at harvest time emphasis was placed on evaluating the degree of protection afforded to the ears. One hundred ears (4 lots of 25 each) were taken from each test plot and the extent and location of injuries as well as the number of borers in husks, silks and kernels was recorded for each ear. Ten plants in each plot were dissected to determine the degree of infestation. A summarization of the results obtained in the most comprehensive field test is presented in Table 1.

The data show that spraying and dusting were about equally effective and that the reductions in the borer population were within the range one might expect from the use of ground equipment. A study of the location of surviving borers is quite revealing. Apparently all treatments gave almost complete control of the borers in the main stalk but borers in the ears were less easily controlled. It also appears that borers that go through the husk and enter the side of the ear are much more easily controlled than those entering the tip of the ear through the silk channel. Perhaps this factor more than any other will make the treatment of canning corn practical and economical. While we would like to eliminate all types of damage, tip damage is not too serious because it can be detected and trimmed easily. Side damage on the ear is much more serious because trimming removes considerable valuable corn and also because borers in the side of the ears are much more likely to escape detection.

A computation of yields per acre showed gains of 17 and 18 per cent, or about ½ ton per acre. Also the corn from the various plots was followed through all the steps prior to actual canning and accurate records were obtained on the amounts of cut corn made available by the various treatments. Cut corn yields from the treated and untreated plots provided data for computing the per cent increase in cut kernel yield as shown in Table 1. These increases may seem rather large at first glance, but one must not overlook the many factors contributing to this gain. By reducing the number of borers in the plant, more of the ears reach maturity, individual ear weight is in-

Table 2.—Control of second generation corn borer on canning corn with 5 per cent DDT at 25 pounds per acre, Rochelle, Illinois, 1946.

Farm	Planting Date	Number of Applications	Borers/100 Plants			Per cent Control Based on	
			Treated	Strip Check	Field Check	Strip Check	Field Check
1	5/28	1	87	236	400	63.1	78.3
1	6/1	2	130	120	500	0.0	74.0
1	6/4	3	122	95	800	0.0	84.8
2	6/11	4	100	296	1750	66.2	94.3
3	6/17	4	208	512	2000	59.4	89.6
4[1]	6/25	4	84	170	1100	50.6	92.4
5	6/28	4	168	320	700	47.5	76.0
5	6/28	5	164	320	700	48.8	76.6

[1] This one farm was sprayed with DDT oil concentrate.

creased, and finally, there will be less trimming of the ears because of the reduction in tip and side damage.

When treated corn (20 per cent tip damaged and 5 per cent side damaged) and untreated corn (33 per cent tip damaged and 25 per cent side damaged) from the same field was simultaneously run on the two sorting belts in the factory, it was found that 5 men could easily handle all of the trimming required on the treated corn but 20 trimmers working on the untreated corn could not keep up with the work and the belt had to be stopped at intervals. This demonstrated that while the per cent reduction in side and tip injuries were not all we might hope for, the reductions obtained (approximately 70 and 45 per cent respectively) did permit the factory to continue to operate efficiently and at a great saving in labor costs.

These findings in 1945 established the sound economics of borer control on canning corn in a region having a high population level. The sweet corn canners of Illinois were favorably impressed with the 1945 results and gave us wholehearted encouragement and financial support to continue the investigation in 1946.

1946 TESTS.—The airplane experiments in 1946 also were conducted at Rochelle, Illinois, on commercial fields of yellow sweet corn. Dusts were applied with a Cub plane on plots 25 feet or 8 rows wide. Intervening checks were 6 rows wide with 5 row buffers on each side. Aerial applications of concentrate sprays were made with a biplane equipped with a gravity feed boom under the full length of the lower wing. Spray plots were 50 feet or 16 rows wide.

The results from our tests against the first brood corn borer in 1946 are of little or no value because of extremely low borer populations in untreated as well as treated plots. For this reason, only second brood results are being presented, even though several of the evaluations were made against both broods.

In the course of routine inspection of our experimental plots near the end of the treatment schedule, we became aware of the fact that the differences between borer populations in treated and untreated plots would be smaller than we had anticipated. We suspected this to be due to an abnormal reduction of borers in our check

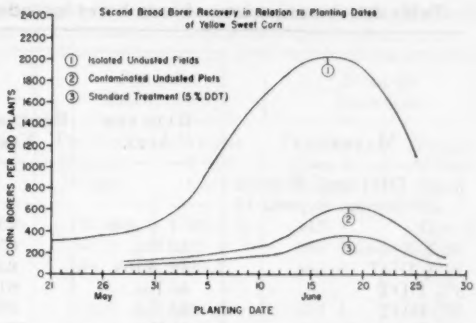

FIG. 1.—Second brood corn borer populations found in undusted fields, contaminated check plots and dusted fields at Rochelle, Illinois, 1946.

strips and possible adult fatalities resulting from dust drift across the field. In order to determine how great this error might be in our experimental fields, it was necessary to survey the community and determine what borer populations were present in fields which were not dusted or exposed to drift from treated fields. A series of examinations in fields of the same corn variety and of the same planting dates as the experimental fields revealed that the normal population in these untreated fields was 3 to 5 times greater than we were measuring in our experimental check plots. These findings are shown in figure 1 along with borer populations found in plots treated with 5 per cent DDT and adjacent check strips. In the results of the following airplane experiments, two figures are shown in the per cent control column; the strip check control is that determined from our contaminated check plots while field check control is based on the borer populations found in undusted fields of the same planting date.

The practical value of corn borer control on canning corn was determined in 1946 by the treatment of 20 to 100 acre fields with 5 per cent DDT at the rate of 25 lbs. per acre. The number of applications varied with the maturity of each field (Table 2). Twenty rows were left on one side of each field to serve as a check on the normal population. Even though eighteen additional rows were used as a buffer, an unexpected amount of contamination occurred from drifting dust. The results based on plant dissections at harvest time are given in Table 2. Appreciable borer reductions occurred in the treated portion of the fields as com-

Table 3.—A comparison of corn borer insecticides applied by airplane, Rochelle, Illinois, 1946.

Materials	Rate per Acre	Borers/100 Ears	Per Cent Clean Ears	Borers/100 Plants	Per Cent Control Based on	
					Strip Check	Field Check
8 oz. DDT/gal. *Velsicol AR-60* plus *Superla 13* oil	1.6 gals.	45	97	137	64	91
40% Ryania	40 lbs.	67	99	150	61	90
10% DDT	12.5 lbs.	65	94	200	48	87
3% DDT	40 lbs.	81	92	220	43	86
5% DDT	25 lbs.	92	97	237	38	85
1% Rotenone	40 lbs.	130	89	362	21	77
Untreated plots	—	139	87	384	—	—
Untreated fields	—	400	55	1550	—	—

pared with the untreated border strips. However, the full magnitude of the good attained is brought out in a comparison of the population in the treated fields with that found in the untreated fields of the community (Field checks).

During both 1945 and 1946, the maximum borer population found in late sweet corn in the vicinity of Rochelle, Illinois, was about 20 borers per plant. During both years the use of insecticides in such fields reduced the population to 2–3 borers per plant.

DDT is gaining popularity as a corn borer insecticide largely because of its low price. Two other insecticides, rotenone and Ryania, have been giving comparable control of the borer in the last three years but their present price is not favorable for large scale usage. Aerial applications of these three toxicants was deemed worth while to determine whether their effectiveness was as good as demonstrated in frequent ground experiments. Three concentrations of DDT dust were included in this comparison and their rates of application were adjusted to give approximately the same amount of actual DDT per acre (1.2 to 1.25 lbs.). One concentrate spray of DDT in oil solution was compared with the five dusts because of its fine performance in the 1945 tests. Four applications were made between August 13 and 30. Results taken at harvest, September 13, are shown in Table 3.

One per cent rotenone dust was the least effective of the six treatments. An eight day delay between the first and second applications might have been partly responsible for this poor showing since rotenone residues are known to be very ineffective after the third or fourth day of application. This is one more reason why the canner is not likely to use rotenone because he would like to place his applications on a weekly basis instead of the 5 day schedule as suggested for rotenone on market sweet corn.

DDT in oil solution gave very promising results. This particular formulation caused a slight burning on rather mature corn during second brood and somewhat more injury to small corn in June. However, yields from this early corn did not indicate any loss resulting from such injury.

Aerial applications of Ryania proved to be very successful. Slight interruptions in our planned 5 day schedule of applications did not seem to impair its efficiency. DDT at 1.2 to 1.25 pounds per acre in dust form, gave similar results whether applied in a 3, 5 or 10 per cent concentration.

Several new insecticides were tested in the field in 1946 but none showed promise in replacing DDT or Ryania. Toxaphene gave fair control but Rothane, a chlorinated hydrocarbon and benzene hexa-

Table 4.—Relative effectiveness of single applications of DDT on second brood corn borer, Rochelle, Illinois.

Application from Normal Schedule	1945 Per Cent Control in Ears		1946 Per Cent Control in Plants
	DDT in Oil Solution	5% DDT Dust 40#/Acre	5% DDT Dust 25#/Acre
First	49	50	37
Second	33	29	34
Third	19	11	8
Fourth	Not applied		5

Table 5.—Plant height and yield records from sweet corn dusted with various insecticides, Rochelle, Illinois, 1946.

Dust	Rate of Application Per Acre, Lbs.	May 28 Planting		June 8 Planting		June 28 Planting	
		Per Cent Gain in Height[1]	Weight of 100 Ears[1]	Per Cent Gain in Height[1]	Weight of 100 Ears[1]	Per Cent Gain in Height[1]	Weight of 100 Ears[1]
5% DDT	50	81.2	74.8 lb.	128.4	63.0 lb.	443.7	61.6 lb.
5% DDT	25	89.0	74.7	130.2	60.9	529.7	62.3
40% Ryania	33	82.3	72.7	138.4	60.7	455.2	63.1
1% gamma-benzene hexachloride	26	82.4	71.0	134.1	60.2	503.4	60.6
Untreated	—	85.7	71.8	134.4	62.5	490.2	62.5

[1] Statistical analysis of heights and weights failed to indicate any significant difference between treatments.

chloride were definitely inferior and methoxy DDT was practically worthless.

The relative value of each treatment in a series of applications for corn borer control was determined in both 1945 and 1946. DDT in oil solution and as a dust was applied by plane in making these evaluations. Results are given in Table 4. These data show that the early applications are by far the most important in reducing second generation corn borers on canning corn. Inadequate protection early in the egg hatching period permits a large proportion of the borers to become established on the relatively mature corn.

EFFECT OF INSECTICIDAL DUSTS ON THE DEVELOPMENT OF SWEET CORN.—To determine whether certain insecticidal dusts have any deterrent or stimulating effects on sweet corn grown for canning, it was necessary to conduct the tests during July on corn that was not being attacked by the borer. Yields and plant growth measurements can be taken in a normal corn borer evaluation of insecticides but the borer reduction itself can markedly influence plant behavior and one cannot separate gains from borer control from direct effect caused by the insecticide. Two of the insecticides used, DDT and benzene hexachloride, were included to determine whether they might reduce growth and yields. Ryania was tested because of its reported ability to make corn grow more vigorously.

Comparable tests were made on yellow sweet corn of three planting dates. The oldest corn, planted May 28, was about 43 inches tall and in midwhorl stage when dust applications started July 12. The second test was on corn planted June 8 which was 32 inches in height at the beginning of treatments. The third test was on the youngest corn available which was planted June 28. This corn was only 10 inches in height when dusting began on July 12. All three tests were dusted on July 12, 17, 22, 26 and the young June 28 corn received two additional applications, August 1 and 7.

Each test was laid out with large buffers between treated plots to reduce contamination by drift. Four replicates within a test provided sufficient data for using statistical methods to determine differences in response. Dusts were applied with a rotary crank duster in order to give complete dust coverage and enable us to determine more accurately the amount of dust applied.

Weekly plant height measurements were made on given plants in each plot. Final height records were made in mid-August. The figures for per cent gain in height shown in Table 5 are based on the growth attained at the time of the last measurement as compared to heights at the beginning of the test, July 12. Harvest records were made as each planting reached canning maturity. These records are shown in Table 5 as weights per 100 ears.

These data fail to show any evidence of either injury or stimulation when compared to like measurements from untreated corn. Differences between treatments were not great enough to be significant when put to a statistical test. The results from using 5% DDT at the overdosed rate of 50 lbs. per acre indicate a wide safety margin in normal commercial applications of DDT to canning type sweet corn.

DDT RESIDUE STUDIES.—With the use of DDT ready for acceptance by the canners, data on the plant residues that

Table 6.—Residue comparisons of DDT applied by three methods on sweet corn.

Method of Application	DDT Residues Expressed in p.p.m.		
	Leaves (By Geigy Co.)	Husks (By American Can Co.)	Kernels (By American Can Co.)
Oil solution	117.3	2.1	0.08
Water emulsion	33.2	1.2	0.04
5% dust	14.9	0.3	0.07

might be encountered were badly needed. Therefore, with the generous assistance of able chemists,[1] DDT residues were determined on certain of our experimental plots.

The first study on this problem was to ascertain the DDT residue remaining on plants after a complete schedule of four applications of 5% DDT at 25 lbs. per acre. Beginning with the day of last application, fifty leaves were gathered at ear height on the stalk, weighed, and then allowed to dry pending subsequent analysis. Additional samples were gathered from the same plot at frequent intervals. The final sample was taken 27 days after the last dusting or 10 days after harvest. The DDT residues found on the foliage at 0, 6, 14, 17, 21, and 27 days after the last application of dust were 71, 40, 8, 15, 20, and 22 p.p.m. respectively. Precipitation during the 27-day period totaled 2 inches.

Another set of samples was taken to show the DDT residue on various plant parts. Entire plants from the same 5 per cent DDT dust plot were gathered 21 days after the last of four applications. Chemical analysis showed that corn foliage carried the largest proportionate amount of DDT, 19.7 p.p.m. Stalks had a much lower residue, 3.2 p.p.m. because of their inherent weight. Husks showed a residue of 2.9 p.p.m. The DDT deposit on the outside husks was no doubt similar to that on the foliage but with most of the husk tissue overlapped and protected, the overall residue was not great. No DDT was found on husked ears or in another sample consisting of kernels cut from the cob.

Residues found on plants treated with DDT in various forms proved to be very enlightening. With all three forms of DDT application, oil solution, water emulsion, and 5 per cent dust, the amount of actual DDT applied per acre approximated one pound. The analyses obtained on plant samples collected 20 days after the last of four applications are shown in Table 6.

In the plots treated with DDT oil spray the DDT residues on leaves and husks were 7 to 8 times greater than those found on dusted plots. This fact helps to explain the high degree of borer control attained with DDT in oil. DDT applied in a water emulsion was less tenacious than when applied in oil solution, but still longer lasting than in a dust. Regardless of the type of dispersal, very little residue was found on kernels themselves. This is reassuring from the standpoint of contamination in the canned product but the high residue on the foliage resulting from the use of an oil concentrate may have an important bearing on feeding crop remnants to cattle.

SUMMARY.—Data were presented from tests conducted in 1945 and 1946 which establish the feasibility of second brood corn borer control on canning corn with insecticides in a region of high borer population. Borer reduction by the use of insecticides results in increased yields, reduced labor requirements in the factory, and affords label protection by reducing the hazard of borer contamination in the canned product.

Ryania dust and DDT in oil solution and as a dust were shown to be suitable insecticides for use in large scale airplane applications where delays in timing are not uncommon. The early applications in a three or four treatment schedule were found to be the most important.

In the absence of a borer infestation DDT, benzene hexachloride and Ryania did not injure or stimulate the growth of the corn.

DDT residues on corn foliage apparently weather rather rapidly at first and more slowly thereafter. Residues were greatest on the foliage and practically nonexistent on the kernels. DDT applied in an oil solution was found to leave much higher residues than when applied as a water emulsion or as a dust. The chances of contaminating the canned product with DDT are very remote. Residues on other plant parts are such that they may have some bearing on the feeding of crop remnants to cattle.

[1] The writers are indebted to Dr. R. W. Pilcher of the American Can Company and Dr. E. L. Bailes of Geigy Co., Inc. who made the facilities of their laboratories available and made the analyses reported in this paper.

Insecticides to Control the European Corn Borer in Field Corn[1]

J. H. Bigger, G. C. Decker, J. M. Wright, and H. B. Petty[2]

The application of insecticides to sweet corn has received considerable attention, but the use of such materials on field corn has generally been considered impractical. Field corn producers in Illinois have been compelled to rely upon delayed planting to escape damage by first generation corn borers. All too often a safe planting date arrived during periods of rainy weather which further delayed planting with the inevitable result that losses were incurred due to reduced yields and increased proportions of immature corn.

In Illinois alone, approximately 100,000 acres of farm land are devoted to the production of hybrid seed corn. The seed corn producers in particular require the full season for the production of a quality product. They feel that the elimination of crop losses due to delayed planting and the cost of removing excess moisture from late corn would more than pay for the cost of insecticide applications and pay dividends on early plantings.

The problem of the field corn producer differs from that of the market gardener, who strives for 100 per cent borer free ears. The hybrid seed producer and field corn grower want insurance against disastrous losses and maximum protection at a minimum cost. A reduction in the amount of stalk breakage and number of dropped ears plus the improvement of quality in their crop are the aims of these men.

History of Project.—On June 20, 1945, the authors located a hybrid nursery on the Lowe farms at Aroma Park which was threatened with a serious borer infestation. The owner graciously made this field available for use in insecticide testing experiments.

The very favorable results obtained on these plots (Table 1) were reported to seed producers, who became enthusiastic and prepared to set up extensive control projects in 1946. They were dissuaded from going to extremes and induced to proceed on a sound experimental basis. Ultimately the Natural History Survey developed a cooperative project with several growers[3] in which over 12,000 acres of seed production fields were treated with insecticides on an experimental or semi-commercial basis in 1946. The results obtained are the basis for the present report.

Plan of Project.—The plots used during 1945 consisted of four blocks of single crosses 10 rows wide and 150 hills long. These were dusted with a 12-outlet power duster (Fig. 1). About 75 per cent of the area was used for testing different insecticides and the remainder for investigations on the timing of operations. Applications were made on June 26, July 2, July 7, and July 12. Materials

[1] Richmond Program Paper.

[2] Associate Entomologist, Entomologist, Assistant Entomologist of the Illinois Nat. Hist. Survey, Extension Entomologist, Ill. Nat. Hist. Survey.

[3] DeKalb Agricultural Association, Inc., Moews Seed Company, Lazier Seed Company, Pfister Hybrid Corn Company, Lowe Seed Company, Arthur Walter Seed Company, and Black and Abbott Farms.

Table 1.—Summary table showing results of insecticide treatments at Aroma Park in 1945.

Corn Hybrid	Treatment	Borers per 100 Plants	Per Cent Control	Net Yield	Per Cent Increase Over Check
M14×R2	Rotenone 1%	55	87	43.2	114.9
K171×940	Rotenone 1%	55	87	128.8	53.2
38-11×WF9	DDT 3% *BL 155*, 1.24%	67	80	100.8	82.3
38-11×WF9	DDT 3% nicotine dry conc. 1.24%	32	91	102.1	85.6
CC10×L317E	Ryania 30%	120	66	88.3	77.0
CC10×L317E	Ryania 50%	70	77	79.6	72.3
WF9×M14	DDT 3%	92	77	53.9	84.6
WF9×M14	DDT 5%	50	87	64.6	39.8
	Average of checks	319	—	51.3	—

Table 2.—Summary of results obtained when time and number of applications were varied in an attempt to determine the most efficient use of 5% DDT dust. Percentage of larval control obtained during 1945 and 1946.

	AROMA PARK—1945 GROUND DUSTING 40 LBS. PER ACRE		WATERMAN—1946 PLANE DUSTING 25 LBS. PER ACRE	
APPLICATION NUMBER[1]	Borers per 100 Plants	Per Cent Control	Borers per 100 Plants	Per Cent Control
1	575	18.3	70	16.3
2	—	—	82	.5
1, 2	465	58.1	94	9.8
3	—	—	40	55.5
1, 3	520	65.4	21	81.5
1, 2, 3	305	82.0	19	81.1
1, 2, 3, 4	380	86.8		
Average of checks	449	—	89.3	—

[1] Indicates number and timing of applications.

used were DDT,[4] rotenone, Ryania, and combinations of DDT and nicotine. Check areas were left in conjunction with each treatment. Treatments were applied by Mr. J. W. Apple and all subsequent data were taken by other members of the Natural History Survey staff.

The 1946 program was planned to increase our knowledge along the following lines: (1) amount and type of material to use; (2) method of application; (3) time of application; (4) number of treatments for economical production; (5) practicability on a commercial basis.

Practically all dust treatments consisted of combinations of DDT in pyrophyllite. The dust was obtained from various sources. For spraying, the emulsifiable concentrates were obtained from two sources, namely: concentrate *A* from Geigy Co., Inc., and *B* from the U. S. Rubber Co.

PRELIMINARY STUDIES.—Naturally the use of insecticides will not show a high net return unless the borer population is high enough to be a factor in production. Therefore, where insecticide treatments are contemplated, a two-fold decision must be made, namely: (1) what fields to treat and (2) when to make the applications. No exact criteria are available upon which to make such decisions; and so the grower must take into consideration population levels, the percentage of pupation and emergence, the rate of oviposition, and the size of the corn involved. As much as possible of this information was supplied to seed producers in the form of reports on the results of fall and spring surveys of abundance, and continuous studies of pupation, emergence, and oviposition trends made by the Survey entomologists and their cooperating agents.

TIMING APPLICATIONS.—Moths began to emerge about June 1 and eggs were first observed on June 10. By June 15 it was evident that treatments should start within a week. On the evening of June 18, heavy rains and wind destroyed a very high percentage of eggs deposited up to that time. Subsequent moderate egg deposition continued up to June 25, and light oviposition occurred as late as July 9.

Basing their judgment upon a study of population and life history records, the entomologists decided that June 20–21 was an appropriate time to start treatment operations on the largest corn. At that time (Table 8) there were approximately 100 egg masses per hundred plants and approximately 15 per cent of these were in the blackhead stage. Pupation was complete and emergence had reached 50 per cent.

The following theoretical dusting schedule was established: Treatment number (1) June 20–21, (2) June 25–26, (3) June 30–July 1, and (4) July 5–6. Only the first generation of borers was considered in this project.

MEASURING RESULTS.—In late July, when about 50 per cent of the larvae present were in the fifth instar, 5 plants at each of 4 places in each treated and untreated plot were dissected and the per cent of infestation was determined by carefully examining 25 plants at each point. From these records, population levels were established.

At harvest time, 4 random samples consisting of the corn from 20 3-plant hills were husked. These samples were sorted to eliminate ears which the seed companies would ordinarily discard prior to drying, and the original and discard weights obtained. The net product was dried, shelled and tested for moisture to obtain requisite data for computing yields. Net yields of bushels per acre at 15.5 per cent moisture are shown in the accompanying tables.

DISCUSSION.—*Timing:* Attempts to

[4] Dichloro-diphenyl-trichloroethane.

Table 3.—Relation of amount of actual DDT applied and concentration of material in applications to control of the borer and resulting net yields.

LOCATION	LBS. PER ACRE OF TOXIC INGREDIENT		PER CENT DDT IN PYROPHYLITE	PER CENT CONTROL	NET YIELD	INCREASE OVER CHECK
Aroma Park Lowe	DDT	1.0	3.0	74.0[1]		
	DDT	1.0	5.0	74.3		
	DDT	1.0	10.0	43.7		
	DDT	1.5	3.0	63.6		
	DDT	1.5	5.0	82.0		
	DDT	1.5	10.0	71.9		
	Ryania	1.6	40.0	98.2		
	Rotenone	.4	1.0	80.3		
Rochelle Lazier	DDT	.75	3.0	63.8[2]	98.5[3]	
	DDT	.75	5.0	77.8	108.1	
	DDT	1.0	3.0	46.9	100.7	
	DDT	1.0	5.0	64.0	107.7	
	DDT	1.5	3.0	83.7	97.3	
	DDT	1.5	5.0	89.4	109.7	
Granville Moews	DDT	.75	3.0	80.4[4]	102.2[5]	23.9%
	DDT	.75	5.0	85.4	94.3	18.4
	DDT	1.0	3.0	85.9	96.8	17.3
	DDT	1.0	5.0	88.2	98.9	24.1
	DDT	1.5	3.0	92.7	96.1	20.6
	DDT	1.5	5.0	97.4	96.3	25.4

[1] Differences significant at 1%—necessary difference at 5%=24.7.
[2] Differences not significant.
[3] Differences significant at 1%—necessary difference at 5%=6.3.
[4] Differences not significant.
[5] Differences significant at 1%—necessary difference at 5%=8.5.

operate timing tests were made at three places. At the Walter farms infestation failed to develop. At the Lazier farm the corn was small and the infestation developed so late that a complete schedule was not warranted. The most complete data were obtained on a farm near Waterman which was growing seed for the Dekalb Agricultural Association, Inc., where combinations of treatments 1, 2 and 3 were applied by airplane in the center of 30-row strips the length of a 40 acre field. Alternate checks were left. A minimum of drifting occurred. Control figures are based on a comparison of the treated area and the average of adjoining checks.

Variability within the field and inability of the owner to destroy weeds in some portions so influenced yields that they were unreliable. In Table 2 the results of these tests are combined with records for the 1945 timing test at Aroma Park. Both areas were treated with 5 per cent DDT dust. Otherwise they differed in location, method of treatment, amount of material used and basic infestation. In spite of these differences and some variability within the data they show remarkable similarity in pointing out the most effective period of application. The records in Table 2 indicate that the later treatments were most important in controlling first generation borers in early corn.

Support for this point is found in records not otherwise shown from Rochelle where treatment number 3 produced 8.0 per cent and treatment number 4 produced 12.1 per cent increases in net yield over check. At Walnut, on the Black and Abbott farms, where only late treatments were applied, one field showed 24.9 per cent increase in net yield over check while another with a very narrow check which was known to be influenced by drift showed 5.0 per cent increase over check.

Again, at Polo, on 80 acres of seed production of the Blackhawk Cooperative Hybrid Seed Corn Company, two late treatments of 25 pounds of 5 per cent DDT dust per acre made at periods 3 and 4 resulted in 21.5 per cent net yield increase.

The results obtained on early sweet corn test plots during 1946 showed the same trend.

In general, during 1946, later treatments gave better control than the early treatments. However, without further

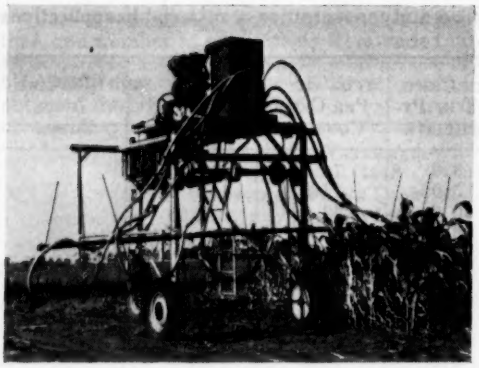

FIG. 1.—A 12-outlet power duster mounted on standard detasseling machine for ground application of dusts. Adaptation first made by entomologists of the Illinois Natural History Survey in cooperation with the Agricultural Engineering Department of the Illinois Agricultural Experiment Station.

FIG. 2.—Sprayer mounted for ground application, El Paso, Illinois. Usable in corn row with stalks up to about 5 feet tall.

evidence, we are not in a position to follow this through to definite recommendations.

AMOUNT AND CONCENTRATION OF MATERIAL.—The results of tests involving the use of different amounts and concentrations of materials are shown in table 3. These data are further summarized in tables 4 and 5. Yield data at Aroma Park are not included because they were definitely unreliable due to drouth conditions which prevailed in this area. At Rochelle a workman inadvertently harvested the check in this experiment and yield increase data are not available. These treatments were all applied with ground machinery.

Available data (Table 4) indicate that, having deposited a minimum of material by the application of 0.75 pounds of actual DDT per acre, we gained no appreciable benefit by increases up to 1.5 pounds of actual DDT per acre. (Differences not significant, Table 3).

The data further indicate that 5 per cent concentrations were more effective than the 3 per cent concentrations. (Table 5.)

METHOD OF APPLICATION.—By scanning all the records of all treatments applied we are led to believe that ground dusting has given somewhat better results than airplane dusting. This may be a misconception, however. Drift of dust is not as widespread when the applications are applied with ground machinery and adequate checks are more easily obtained. Some of the results from airplane dusting operations are undoubtedly obscured by drift over the checks.

Table 4.—Summary table showing effect of amount of actual DDT applied on control and yield.

LOCATION	LBS. DDT PER ACRE	PER CENT CONTROL	NET YIELD	PER CENT INCREASE OVER CHECK
Aroma Park	1.0	64.1		
Lowe	1.5	72.8		
Rochelle	.75	70.8	103.5	
Lazier	1.0	55.5	104.2	
	1.5	86.6	103.8	
Granville	.75	93.1	98.3	21.2
Moews	1.0	87.0	98.2	21.3
	1.5	94.5	96.7	23.0

Table 5.—Summary table showing effect of concentration of DDT in pyrophyllite dust applied upon control and yield.

LOCATION	PER CENT DDT	PER CENT CONTROL	NET YIELD	PER CENT INCREASE OVER CHECK
Aroma Park	3.0	69.2		
Lowe	5.0	79.3		
	10.0	59.5		
Rochelle	3.0	64.8	98.8	
Lazier	5.0	77.1	108.5	
Granville	3.0	86.1	98.4	20.6
Moews	5.0	90.0	96.8	21.7

Table 6.—Comparative effect of dusting and spraying of field corn with various amounts of DDT from different sources and all applied by plane.

SOURCE OF INSECTICIDE	AMOUNT PER ACRE	TYPE OF APPLICATION	LBS. PER ACRE TOXIC INGREDIENT	BORERS PER 100 PLANTS	PER CENT CONTROL[1]	NET YIELD[2]	PER CENT INCREASE OVER CHECK
Emulsifiable concentrate (B)	8 ounces—25% DDT concentrate	Spray	.12	135.0	40.7	85.8	.4
Oil Dust	25 lbs. 5% DDT in pyrophyllite plus 2% oil	Dust	1.25	22.8	90.0	103.3	20.9
Check	none	—	—	227.7	—	85.5	—
Dry Dust	25 lbs. 5% DDT in pyrophyllite	Dust	1.25	66.6	70.8	96.9	13.4
Oil spray	2 gal.—50% DDT concentrate	Spray	1.0	17.8	92.2	92.9	8.7

[1] Differences significant at 5% level. Necessary difference = 30.9.
[2] Differences significant at 5% level. Necessary difference at 5% = 8.6.

In one test, airplane spraying was compared with airplane dusting. Table 6 shows the results of the experiment in which both dry mechanically mixed and oil impregnated dusts and two spray materials were used. The spray with emulsifiable concentrate B included so little DDT that the treatment was ineffective. The DDT-oil concentrate spray did considerable damage to the plants and this is probably responsible for the reduced yield shown. The damage appears to be traceable to solvents used in the concentrate. Where approximately equal amounts of DDT were used it is apparent that the oil concentrate spray was superior to dry dust. It appears that the differential may be reduced by adding small amounts of oil to the dust. The advantage in favor of spraying is in agreement with observa-

Table 7.—Results obtained by spraying with ground machine with various sources of DDT.

SOURCE OF INSECTICIDE	AMOUNT PER ACRE	LBS. PER ACRE, TOXIC INGREDIENT	DATE OF APPLICATION	BORERS PER 100 PLANTS	PER CENT CONTROL	NET YIELD	PER CENT INCREASE OVER CHECK
Emulsifiable concentrate (A)	1 qt.—25% DDT concentrate	.5	4	35.7	66.0	124.0	7.9
Check	none	—	—	105.0	—	114.9	—
Emulsifiable concentrate (A)	1 qt.—25% DDT concentrate	.5	3	6.8	85.6	119.1	5.8
Check	none	—	—	47.2	—	112.6	—
Wettable Powder	2 lbs.—50% DDT material	1.0	4	1.5	96.8	125.9	12.8
Emulsifiable concentrate (B)	1.6 qt.—25% DDT concentrate	.8	4	1.8	96.1	117.2	5.0
Emulsifiable concentrate (A)	1.6 qt.—25% DDT concentrate	.8	4	.5	98.9	124.3	11.4
Check	none	—	—	46.4	—	111.6	—

Table 8.—Results of semi-commercial tests on farms of contract growers of seed corn near Waterman, De Kalb County, during 1946.

Field	Date of Planting	Egg Masses per 100 Plants June 21–22		Plant Height Extended June 21–22	Treatment Number	Control	Increase in Net Yield Over Check
		White	Blackhead				
	May	No.	No.	In.	No.	Pct.	Pct.
Black & Watson	?	80	20	24.0	1	24.4	10.2
A. Totel	13–14	120		20.2	2	—	6.6
D. Totel	13-14	100		21.0	2	—	17.7
Rompf	13–15	84	24	19.9	2	3.2	7.8
Guehler	13–14	96	16	21.6	1, 2	22.8	10.8
Johnson & Townsend	7– 8	72	24	24.1	1, 3	—	13.4
Dolder	9	96		22.3	2, 3	80.8	2.8
Wielert	9–13	144	24	21.3	2, 3	48.5	12.1
Sanderson	10–11	100	4	19.9	2, 3	21.8	7.6
Colton West	6– 7	148	36	22.5	1, 2, 3	63.4	13.9

tions made in other places where spraying has been observed.

The only widespread ground spraying operation was carried on by Mr. Pfister at El Paso and Minonk (Table 7). All applications were made late in the treating period (June 29 to July 6) and excellent results were obtained. The apparatus used is shown in figure 2. We were able to sample only about 200 of the 1500 acres treated by Mr. Pfister but he is enthusiastic regarding the results obtained on all of his treated acreage. Further tests of this method must be carried on before any real conclusions can be drawn.

Number of Applications.—Data included in the tables appear to indicate that in 1946 a single application made at a strategic time gave practically as good results as multiple applications. This happened during a season when a very large percentage of the early eggs were destroyed by beating rains and is not suitable basis for a recommendation.

Commercial Application.—Near Waterman, semi-commercial treatments were applied on 10 farms contracting production for the De Kalb Agricultural Association, Inc. Results are given in table 8.

It is shown that in spite of variability in soil fertility, cultural practices, infestation, time of planting and treatment, 9 of the 10 farms produced sufficient net yield increase over checks to pay dividends over and above the cost of treatment. This, after all, is the actual proving ground for the practice.

We also have records of a farmer near Tonica who hired about 100 acres of field corn treated by plane with 5 per cent DDT dust, and left several acres in the center of the field untreated. Records made on his farm show 25.0 per cent control of borers and a net yield increase of 6.1 per cent. This single treatment on ordinary farm corn paid dividends over the cost of treatment. Several other farmers who made single treatments late in the season report equally satisfactory results.

Incidentally, we have found a few dead moths in treated fields but to date have been unable to establish a definite correlation between treatment and moth activity. In both years there was evidence indicating reduced oviposition in treated fields.

The costs of treating field corn with insecticides vary greatly depending upon the method of application, number of acres treated and the type and amount of materials used. The best figures available, based upon the experiences of 1945 and 1946, indicate that the cost of treatment per acre per application, excluding original cost of equipment, is as follows: Spraying with ground equipment, $1.75 to $2.00; dusting with ground equipment, $2.00 to $2.50, and dusting or spraying by airplane, $2.75 to $3.50. These figures do not include the cost of obtaining population and life history information which determine the treating schedule.

Summary and Conclusions.—Production of hybrid field corn seed is an important industry in Illinois. Delays in planting to avoid first generation corn borer damage frequently lead to losses.

During 1945 applications of insecticides to single cross hybrids were markedly successful in reducing borer damage and increasing marketable seed.

Results of the 1946 grower-station cooperative tests indicate that, having deposited a minimum amount of material, additional amounts gave no appreciable benefit. It appears that 5 per cent DDT dust is more effective than 3 per cent DDT dust.

During both 1945 and 1946 the later treatments gave better control than early applications. The results suggest that one or two timely applications may be sufficient for field corn protection. Ground machinery appears to give better control than airplane applications. Sprays are possibly better than dry dusts. Oil impregnated dust may be equivalent to sprays.

Treatments such as were applied during 1946 are shown to be economical on hybrid seed production acreage and possibly on farmers' fields during periods of moderate to heavy infestation by first generation borer.

Costs per application per acre range from $1.75 to $3.50 for materials and labor, depending upon the materials used and method of application.

Some possible advantages of insecticide program:

1. Permit the grower to plant as early as soil conditions are favorable.
2. Provide insurance against possible borer damage when the infestation is uncertain.
3. Under moderate to severe infestation (a) increase net yields, (b) raise quality and grading per cent, (c) reduce loss due to dropped ears.—1-15-47

Variations in the Seasonal History of the European Corn Borer in Ohio

C. R. NEISWANDER, *Ohio Agricultural Experiment Station, Wooster*

During the first few years after the European corn borer was introduced in the Central States region of the United States, extensive studies were made on its seasonal history in northwestern Ohio. Poos (1927) at Sandusky and Huber *et al.* (1928) at Oak Harbor, presented data showing the seasonal occurrence of the various stages of the insect. The observations of these investigators were made over a period of about 5 years with practically identical results. Both reports recorded a single generation per year with the maximum moth flight period occurring about July 5.

The appearance of a partial second generation was reported by Vance (1939) in northwestern Ohio and northeastern Indiana during the summers of 1936 and 1937. In 25 fields of sweet corn that were studied in 1936, Vance found an average summer pupation of 6.2 per cent. In 25 fields in 1937, the average summer pupation was 8.7 per cent. This marked an important change in behavior because during the preceding years the number of pupae taken in the summer in Ohio had been negligible. However, Ficht (1936) had reported that a partial second brood occurred in Indiana in both 1934 and 1935.

Coincident with the change from a single generation to a two generation type of behavior, Vance noted that the moths of second generation borers emerged about a week earlier the following spring than did those of the single generation borers. In one of his concluding paragraphs he stated that "The widespread occurrence of a partial second generation in several of the Lake States offers justification for the belief that the so-called 'single generation strain' in certain regions is modifying its response to environment and is now in a state of transition, with a tendency toward an increased proportion of the two generation form."

The writer is in accord with Vance's statement and is of the opinion that the transition has progressed to a point where the entire hibernating borer population now transforms to moths much earlier than it did when there was but a single generation per year. In the spring of 1944 and 1945 moth emergence data were obtained from two types of corn fields at Van Wert, one of which contained largely second generation borers the preceding year and the other largely single genera-

tion borers. In both years the moth emergence periods for the paired fields were practically identical, regardless of the difference in the number of generations the preceding year.

In this paper the writer will discuss (a) the recent seasonal advance in the moth flight period of the hibernating generation in northern Ohio, (b) the present variation in the time of occurrence of this period across the state in a north-south direction, (c) the period of emergence of summer generation moths, and (d) the variation in the time and amount of summer moth emergence from different hosts.

During the years 1943 to 1946, observations on seasonal behavior were made at several points in the state. The map (Fig. 1) shows the location of the areas studied. The most northerly and the most southerly points have a difference in latitude of a little more than 2 degrees or about 150 miles. In all these localities the seasonal history records were taken on borers in corn stalk remnants from fields that had been in dent corn the preceding year. In most instances these fields were in oats at the time the data were taken.

The records were obtained from the fields at approximately weekly intervals during the insect transformation period by dissecting corn stalks until a total of 50 larvae, pupae, and cast pupal skins had been observed. The number in each stage was noted. From the data obtained, the percentage of moth emergence was calculated for each locality and observation date, and moth emergence curves were constructed.

ADVANCE IN THE FLIGHT PERIOD OF THE HIBERNATING GENERATION.—The emergence record for the hibernating generation at Elyria is shown in figure 2 for the years 1944, 45 and 46. It may be noted that moth emergence at Elyria in 1944 was about 5 or 6 days earlier than in 1945, and for 1946 it was intermediate between that of the other 2 years. In 1944 the May-June temperature was 6.3° F. higher than the 74-year average at Cleveland (Andrus 1945), whereas in 1945 it was 2.3° F. lower than the average and in 1946 it was practically the same as the average. These differences in May-June temperatures probably account for much of the variation in time of corn borer emergence for the 3-year period.

The average emergence curve for the years 1924–1927, as presented by Huber *et al.* (1928), is shown also in figure 2. When a comparison is made of the average moth emergence period for the years 1924 to 1927 with that of the years 1944 to 1946, it can be seen that a difference of

FIG. 1.—Location of stations at which corn borer seasonal history records were taken.

approximately 2 weeks was maintained throughout the period of transformation. Furthermore, the moth emergence curve for the abnormally cold May and June of 1945 was still 10 to 12 days earlier than that of the 1924 to 1927 average. Although the average May-June temperature for the period 1924 to 1927 was somewhat lower than the 74-year average, it was not as low as the May-June 1945 temperature. Hence the indicated difference in the moth emergence period cannot be attributed to a variation in May-June temperatures. It appears therefore that, coincident with the change from a single generation to a two-generation type of behavior, the hibernating generation has advanced its period of emergence approximately 2 weeks in northern Ohio, and that the average date of maximum moth flight is now about June 20 instead of July 5.

VARIATION IN MOTH FLIGHT PERIOD FROM NORTH TO SOUTH.—During the period of 1943 to 1946 the writer has also studied the seasonal history of the insect in other parts of the State. The variation that occurred in 1946 at four stations distributed over the State in a north-south

direction is shown in figure 3. It may be noted that between the most southerly and the most northerly points there was a constant difference of approximately 2 weeks in moth emergence. In stations located intermediately the insect likewise was intermediate in its seasonal history development. Although moth emergence was earlier at the more southerly points, the variation in seasonal behavior between stations was not quite proportional to the variation in latitude. For instance, the curve for New Carlisle is nearer that of the Van Wert area than it is to the

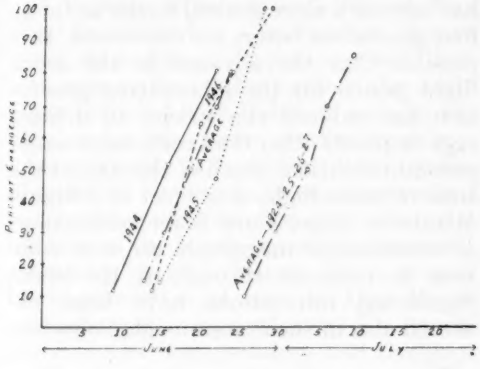

FIG. 2.—Emergence period for moths of the hibernating generation in northern Ohio for the years 1944 to 1946 as compared with that of the average for the years 1924 to 1927.

Cincinnati area although in latitude New Carlisle is nearer Cincinnati than it is Van Wert. Such inconsistencies may be expected to occur in any year depending upon the local climatic conditions.

Records for each of these localities are available for 2, 3, or 4 of the years from 1943 to 1946. Average curves for the years in which records were taken are presented in figure 4. These curves may be considered as guides to the probable period of moth flight for each of the localities. However, it must be understood that the period of moth emergence in any one of the areas could vary several days from the average in either direction as was shown by the 3-year records taken at Elyria (Fig. 2).

SUMMER FLIGHT PERIOD.—The period of moth emergence for the summer flight as well as the total amount of emergence of this generation has varied greatly with the season, with the latitude of the locality observed, the nature of the host crop, the

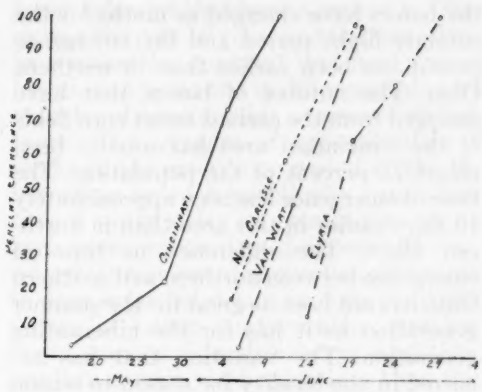

FIG. 3.—Emergence period for moths of the hibernating generation in 1946 at four localities across the state in a north-south direction.

earliness of planting, and the earliness of maturity of the host. Because of these many qualifying factors, there has been considerable variation in the time of appearance of this generation.

The summer moth emergence period taken from early market garden sweet corn at Elyria in northern Ohio for the three seasons 1944, 1945, and 1946 is shown in figure 5. It may be noted that a difference in the flight period of about 3 weeks occurred between the 1944 and 1945 seasons. The percentage of borers

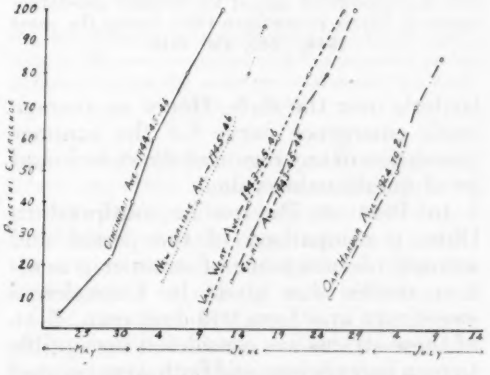

FIG. 4.—Average emergence periods for moths of the hibernating generation at four different localities in the state during the period 1943 to 1946 as compared with the average at Oak Harbor in northern Ohio during the period 1924 to 1927.

that emerged also varied for these 3 years in the same locality. In 1944 the highest percentage of emergence observed was 45 whereas in 1945 it was 24.

In southern Ohio a higher percentage of

the borers have emerged as moths for the summer flight period and the emergence period has been earlier than in northern Ohio. The number of borers that have emerged from the earliest sweet corn fields of the Cincinnati area has usually been about 75 percent of the population. The time of emergence has been approximately 10 days earlier in this area than in northern Ohio. The difference in time of emergence between northern and southern Ohio has not been as great for the summer generation as it has for the hibernating generation. The variation that has occurred in one locality for season to season has been greater than the variation by

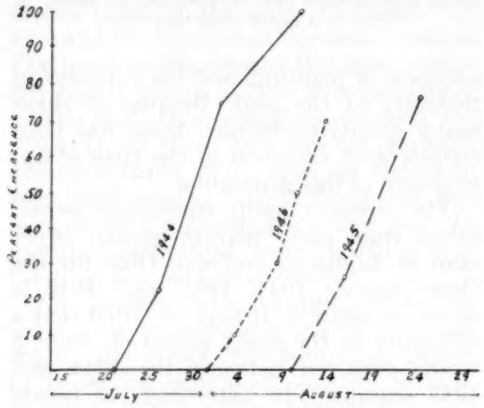

FIG. 5.—Emergence period for summer generation moths at Elyria in northern Ohio during the years 1944, 1945, and 1946.

latitude over the state. Hence an average moth emergence curve for the summer generation in any region of the state would be of questionable value.

In 1944 at Dayton in southwestern Ohio, a comparison of the period and amount of emergence of summer generation moths was made in Carmelcross sweet corn and Iowa 939 dent corn. Both of these strains are considered susceptible to corn borer injury and both were planted in early May. The moth emergence curves for the summer flight period are shown in figure 6. In these two curves the actual percentage of moth emergence is shown for all dates. It can be noted that emregence started later in Iowa 939 and the total that emerged was less than in Carmelcross. But little emergence occurred after August 10 from either strain. Differences in time and amount of summer moth emergence such as is shown in figure 6 have been observed repeatedly in recent years. The same differences appear when early maturing sweet corns are compared with late maturing sweet corns, or early dent corns with late dent corns. Just as a higher borer survival occurs in early maturing corn strains, likewise a higher percentage of summer moths emerge for a second generation from those strains (Neiswander–1945).

SUMMER EMERGENCE FROM DIFFERENT HOSTS.—Coincident with the change from a single generation to a two-generation type of behavior, the corn borer in Ohio has become a more general feeder as far as first generation borers are concerned. It is possible that the advance in the moth flight period for the hibernating generation has induced the species to deposit eggs on plants other than corn, since under present conditions much of the corn at the time of moth flight is not yet in a highly attractive stage. Corn borer infestations of considerable magnitude are now common in potatoes throughout the state. Significant infestations have been observed also in such crops as gladiolus and

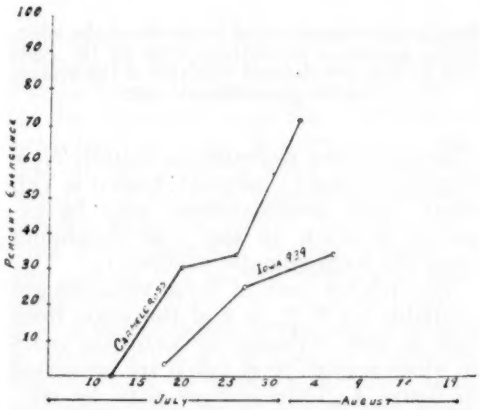

FIG. 6.—Emergence period for summer generation moths from Carmelcross sweet corn and Iowa 939 dent corn at Dayton, Ohio in 1944.

peony. Corn borer development in at least one of these hosts seems to be more rapid than in corn.

A comparison of borer development in early sweet corn and potatoes was made at New Carlisle, Ohio in 1946. The pupation and emergence curves for these two crops are shown in figure 7. It can be noted that both pupation and emergence were 3 to 4

days earlier for the borers infesting potatoes than for those infesting corn. The sweet corn was Marcross, a susceptible strain, planted April 24 and 25. The record for potatoes was taken from two fields, one of which was Cobbler and the other Katahdin. It is interesting to note that both pupation and emergence started earlier in the early maturing Cobblers than in the late maturing Katahdins. This suggests that the factor that permits a higher survival and more rapid growth of the borers infesting early maturing strains of corn as compared with late strains may produce a like result in potatoes.

A similar situation occurred at Van Wert in 1946 when a comparison of corn borer development in potatoes and dent corn was made. In this instance the study again included both Cobblers and Katahdins and again borer development was more advanced in the Cobblers than in the Katahdins. However, the most interesting development in this study was that 100 per cent of the borers in potatoes emerged as moths in mid-summer for a second larval generation whereas less than 25 per cent emerged from dent corn. The emergence record from potatoes and the very small pupation record from corn are shown in figure 8. The corn was planted May 9, which is early for the Van Wert area, and should have been relatively favorable for rapid borer development. However, during the 4 years 1943 to 46 the writer has never observed more than 35 per cent summer emergence from dent corn in the Van Wert area.

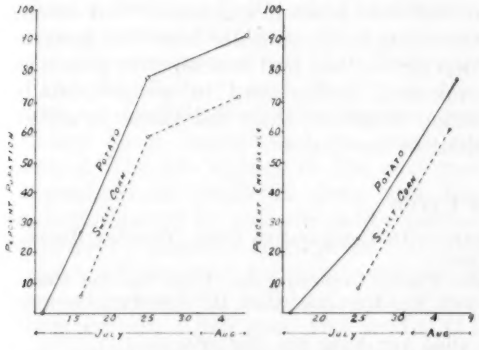

FIG. 7.—Comparison of summer pupation and emergence periods from potato and sweet corn at New Carlisle in 1946.

DISCUSSION.—The changes in corn borer behavior that have occurred in Ohio during the past 10 years and the variations in seasonal development that now prevail in different hosts and in different latitudes may be of considerable economic importance. The advance of approximately 2 weeks in the emergence period of the hibernating brood is practically equivalent to a 2 weeks delay in planting as far as corn borer survival in dent corn is concerned. It now seems of questionable value to urge extended delays in corn planting, especially since unfavorable weather might cause still further delays, and thus result in greater yield reductions than the borer itself would have caused if the corn

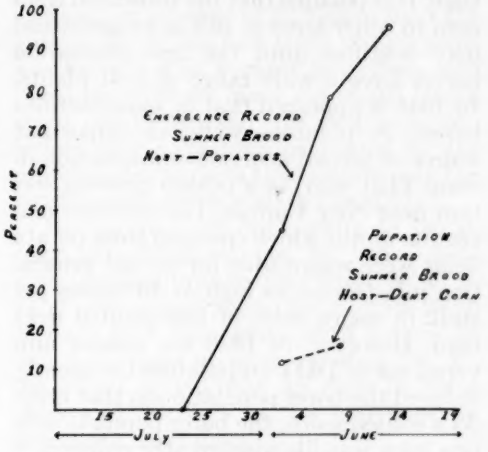

FIG. 8.—Emergence period for summer brood moths from potatoes as compared with the pupation period in dent corn for the same generation at Van Wert, Ohio in 1946.

had been planted early. The reduced borer survival that necessarily follows earlier egg deposition has greatly reduced the hazard of early planting. As a result, the writer is inclined to advise only the avoidance of extremely early plantings.

The appearance of moths of the hibernating brood 2 weeks earlier in southern than in northern Ohio suggests that no one planting date can be designated for all parts of the state. As far as corn borer injury to dent corn is concerned, a May 10 planting in southern Ohio should be equivalent to a May 24 date in northern Ohio. In selecting planting dates for corn borer control it should also be borne in mind that late plantings are likely to have significant populations of second generation borers.

The variation in the time of appearance of moths of the hibernating generation is also of importance to sweet corn growers in timing their insecticide applications. In southern Ohio, growers should be ready to start the application of insecticides by June 5 whereas in northern Ohio it is seldom necessary to start before June 20. The actual time of application of course cannot be determined in advance for any locality but will depend upon the time of egg-hatch which varies with the earliness or lateness of the season.

The importance of hosts other than corn on the general corn borer population level is difficult to evaluate at the present time. It is possible that the transition from corn to other hosts is still in progress and may continue until the first generation borers have a wide range of host plants. In 1945 it appeared that in some sections borers in potatoes were an important source of second generation infestation in corn. That year, in a potato growing section near New Carlisle, the summer generation moths which emerged from potato fields were responsible for second generation infestations as high as 10 borers per stalk in many fields of late-planted dent corn. However, in 1946 the almost universal use of DDT on potatoes has greatly reduced the borer population in that crop. As a consequence, the borer population in late corn was likewise greatly reduced.

The behavior of the corn borer during the past 4 years has greatly changed the investigational problem, but whether the importance of the insect as a destructive agricultural pest has been increased or diminished remains to be seen. The writer is inclined to believe that the insect, in changing its seasonal history, has reduced its potentiality on early planted dent corn, although it may become increasingly important on other agricultural crops.

SUMMARY.—Concurrent with the change from a single generation to a multiple generation type of behavior, the period of moth emergence for the hibernating generation of the European corn borer has advanced about 2 weeks in northern Ohio. The peak of the moth flight period during the years 1924 to 1927 was about July 5, whereas during the years 1943 to 1946 it was approximately June 20.

Seasonal history studies made at four points in the state during the years 1943 to 1946 showed that in southern Ohio the hibernating generation emerged about 2 weeks earlier than in northern Ohio. At intermediate points the emergence period was also intermediate.

The time of emergence of summer generation moths as well as the magnitude of the summer moth flight has varied greatly with the locality, the season, and the host. In the earliest maturing sweet corns in southern Ohio, about 75 per cent of the first generation borers have emerged as summer generation moths, whereas in northern Ohio the average has been about 35 per cent.

In a comparison of borer development in different hosts it was found that moths emerging in the summer from first generation larvae that had developed in potatoes appeared earlier and in proportionally larger numbers than did those in either dent or sweet corn.

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Biology and Control of the Allegheny Mound Ant[1,2]

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Formica exsectoides, the Allegheny mound ant, was described by Forel (1886) in 1886. Ten years prior to this, McCook (1877) had studied these ants at Hollidaysburg, Pa., under the name *Formica rufa*. While visiting America in 1899, Forel (1899) mentions observing colonies at Worchester, Mass., Cromwell, and Hartford, Conn., and Black Mountain, N.C. In 1891, Dalla-Torre (1891) lists this ant as occuring in "Am. North (New) Hampshire, Conn., Alleghanies." According to Wheeler (1913), who mentions the ant in a number of his works, this species is distributed from Nova Scotia to Georgia and from the Atlantic Coast to the western side of the Appalachian Mountains and occasionally as far west as Colorado.

During the last 25 years several persons have studied the Allegheny mound ant. Andrews made a number of studies on the habits of this ant, including observations on the food used and a population study (Andrews 1929b and a).

In 1938 another population study (Cory & Haviland 1938) showed that a mound 19 inches high contained 237,103 workers and 1407 queens, and an 11-inch mound contained 41,326 workers and 40 queens. From a study of 10 acres, averaging seven mounds to the acre, the population was estimated to be about 12 million ants.

The life history and habits of this species, especially the feeding habits, were studied as a background for work on control. The life history of the ants was determined in artificial nests and the seasonal history by periodic field observations over a period of three years.

LIFE HISTORY.—*Formica exsectoides* eggs are elongate, elliptical and white. They average 0.823 mm. long and 0.413 mm. wide at the widest point. The surface is slightly granular and sticky which makes the eggs adhere to each other. In 30 artificial nests, held at 70° F., eggs hatched in a range of 10 to 27 days, with an average of 19.4 days. In 19 artificial nests, with the temperature varying from 48° F. to 94° F., egg hatching ranged from 11 to 54 days with an average of 21 days.

The curved, legless, white larvae were kept in groups on the floor of the nest. In eight nests with temperatures varying from 48° to 94° F., it took from 11 to 53 days from the time the first larva was noted until a pupa was formed; an average of 18.2 days. In nine nests held at approximately 70° F., it took from 21 to 53 days; an average of 37.1 days from the appearance of the first larva until a pupa was formed. The workers have been seen to eat large larvae. Since individual larvae could not be marked, the first larva observed may have been consumed by the cannibalistic workers thus lengthening the larval period as recorded in this study.

The cocoons are dirty white to tan in color depending on age. In seven nests with temperatures varying from 48° F. to 94° F., the pupal period lasted from 22 to 35 days with an average of 27.3 days. In four nests held at approximately 70° F., the pupal period was 25 days in three cases and 30 days in the fourth or an average of 26.25 days.

In 11 nests for which the length of each stage is known, the total time required from first eggs to the appearance of a callow was from 54 to 107 days or an average of 75 days. The cannibalistic habits of the workers may account for the wide range. The lengths of the various stages in the development of *Formica exsectoides* are similar to those for other species of ants as determined by various workers.

The callow is much lighter in color than the workers and for a period of about 2 weeks can be distinguished from the others. In nature the workers vary in size. The largest are almost like soldiers. The smallest are two-thirds this size and lighter in color. Intermediate sizes are present, but the gradation is too varied to make distinct groups. All workers raised in artificial nests with one or more queens were the smaller type.

In the absence of a queen, workers produced eggs but at a lower rate than

[1] This paper is based on a thesis presented to the Graduate School of the University of Maryland in partial fulfillment of the requirements for the degree, doctor of philosophy. The author is grateful to Dr. Ernest N. Cory for suggesting the problem and for valuable advice throughout.

[2] Scientific Journal Article A107, contribution No. 1983 of the Maryland Agricultural Experiment Station, Department of Entomology.

was normal in artificial nests. Egg laying was slow in starting and was discontinued after 2 weeks. Only males were produced from worker eggs.

HABITS.—The mounds of the Allegheny mound ant are rounded cones from 1 to 3 feet high, often asymmetrical because of vegetation, slope, injury, and shading. Usually, part of the mound proper is bare unless the colony is very weak. Colonies that have moved recently usually have grass and weeds protruding at the top of the nest and may surround a small tree. Most of the grasses and weeds are dead by the next summer, but the tree may persist. In the open, the ants may not keep the mound free of plant growth except near the top and most of the southwest side. In shaded locations, the mound is kept entirely free of growing plants. Most colonies have grass and weeds around the base of the mound, or the leaves and sticks of the forest litter come up to it, obscuring the entrance holes.

All mounds opened showed the same general structure. The passageways were roughly cylindrical and about a half-inch in diameter. In the mound, the wall between passageways was about a half-inch thick. The outer layer was almost twice that thick and of a slightly firmer construction. In vertical section the passageways of the mound appeared to be arranged in stories. Each passageway sloped up or down after a few inches so that there were almost as many communications between stories as there were passageways. The passageways branched and united frequently. There was no sharp dividing line between the mound which had been built by the ants and the region below, which had been excavated.

For a foot below the soil level and a foot from the base of the mound, the passageways were as numerous as in the mound. Deeper in the soil, the passageways were farther apart and more of them were vertical. They extended to a depth of from 30 to 36 inches.

In the spring, the first outside activity of the ants is to repair the mound. In the fall, the last activity is to add soil to the outside of the mound. At all times during the active season, the mound is kept in repair. If some part of the mound is destroyed, this is built more rapidly than the rest. Grasses and other plants that have sprouted on the mound are killed or die. Sometimes the vegetation is killed back as much as a foot around the base of a mound. Usually when the ants prune back encroaching vegetation, it is done gradually and is not noticeable except that the plants never cover the mound.

In Maryland, mounds are usually found where there is some opening in the forest or at its edge. As the trees grow larger and the area becomes shady, the ant colonies move or die out and no swarms become established. Colonies will move when disturbed often or when the mound is treated with some distasteful material. This habit of moving and the establishment of new mounds by swarming are important when control is attempted.

SEASONAL HISTORY.—Depending upon the season and the exposure of the mound, these ants hibernate in the burrows below the mound from October until April at Beltsville, Maryland. Temperature variations seem to be the most important factor in determining the time hibernation begins and terminates. By the last week in April dealated queens can be found near the surface of the mound. By the last week of May, mounds contain large numbers of larvae of all sizes. Large steep-sided mounds contain large numbers of large larvae, which will develop into kings and queens, and many smaller larvae that presumably develop into workers. Most small mounds do not contain the large "royal" larvae.

During the months that the colonies are active, the mound proper and the first 6 inches below soil level are used most. Larvae and pupae are gathered in the passageways with little segregation by sizes. In hot, dry weather in mounds fully exposed to the sun, the ants concentrate the brood below soil level on the north and east sides of the mound. In mounds only partly exposed to the sun, or in cool weather the brood is kept on the sunny side in the mounds, above soil level.

From the first week in June until September, pupae are present. In strong colonies, at first most of the pupae are "royals." After about 5 weeks, worker pupae are all that can be found.

The last week of June, winged males and females are present near soil level in the mounds. When disturbed they make little or no effort to fly. Winged forms disappear by the middle of July.

In August, the activities of the colonies

decrease gradually, few larvae are present and the numbers of pupae found become less and less. By mid-September, many of the ants are down in the tunnels, below the mound proper, entering hibernation. The numbers hibernating and their depth in the burrows increase as the season advanced. No eggs, larvae or pupae are found in the mound from October to April. Workers and dealated queens are the only forms that hibernated. A populous colony contains more queens in proportion to workers than a small one. No aphid eggs, stores of food or anything except myrmechophiles are found with the ants in the mound during the winter.

Spreading by swarming was carried on in the spring and was a gradual process. The first indication was a few holes with pellets of dirt around them and workers moving in and out. The new location may be from a few feet to some rods distant from the parent colony. Between this spot and the parent colony, the ants are more numerous than at other points on the entire surface of the ground. In a few days, a small loose mound hides the original holes. The number of ants moving between the two mounds still remains large. In a 25-square yard area, burned over during the winter, seven new colonies were found developing. In other parts of this burned section, small new mounds were found that must have been started by ants from a distance of at least 30 yards.

In April when the colonies become active, foraging for food begins and this increases until the middle of July. For the next 2 months it decreases gradually. Two types of food are used. Workers have been found dismembering or carrying Japanese beetles, May beetles, small ground beetles, sowbugs, spiders, crickets, small lepidopterous larvae, crane flies, grasshoppers, termites, and unidentified hymenopterous and dipterous insects. Apparently any insect found that can be overcome is used. This forms one type of food, mainly protein. The other is the honeydew obtained from any honeydew-producing insects present on the trees and bushes.

During the summers of 1943 and 1944 these ants used the honeydew from two generations of the tree-hopper *Vanduzea arcuata* (Say.) on black locust, from the scale *Toumeyella liriodendri* (Gmel.), on the tulip tree, aphids on aspen leaves and aphids on various species of oaks. In 1943 the black aphids on Virginia pines and the aphids on the twigs of chinquapin were used as sources of honeydew. These insects were not present in 1944. The honeydew secured from insects on black locust, tulip tree and oaks was more than that from other sources. No evidence was found that these honeydew-producing insects' bodies were used for food or that they were moved to more advantageous places. The honeydew was simply used as the source of carbohydrate food.

NUTRITIONAL STUDIES.—The nutrition of *Formica exsectoides* was studied by offering various food to the ants in the field, by determining the survival of confined workers on various foods, and by feeding artificial colonies.

Field feeding tests showed that cooked beef, beef broth, raw and cooked liver, liver broth, diluted honey, diluted honey dew honey, and a solution of sucrose were acceptable foods. No food was found which attracted the workers in sufficient numbers to be effective as the basis for a poison bait.

Survival of workers on 21 foods, water, and no food or water was determined in a total of 73 tests conducted at intervals during a year. In all survival tests the food-moistened-cotton was changed three times a week to prevent spoiling.

Ants without food or water gave the lowest survival time. Most of the ants were dead by the third day and none survived 7 days. Workers given water only were able to survive almost twice as long, and a few of them lived 30 days. The foods tested were combinations of a carbohydrate and a protein. Honey, sucrose, levulose, and dextrose were the carbohydrates used. The honey was used in 50 and 25 per cent strengths. The latter has approximately the same sugar concentration as the nectar of flowers (Eckert & Allenger 1939). Honey also contains minerals (Schuette et al. 1937, '38, '39) and vitamins (Kitzes et al. 1943). Honey in 25 per cent concentration gave higher survival when used alone or with every protein tried than 50 per cent honey. Sucrose, 12 per cent concentration, in liver broth gave the highest survival. Levulose or dextrose, 12 per cent, was nearly as good. Doubling the concentration of any of the pure sugars reduced the

survival rate. Sucrose and levulose in 25 per cent concentration gave lower survival than 25 per cent honey.

The proteins tried were liver broth, liver extract, yeast cells, and yeast extract. All of these foods also contain minerals and vitamins (Bradley 1931). The liver extract was used in two strengths The less concentrated solution, 250 milligrams per 100 cc. of solution, gave better survival than 500 milligrams per 100 cc. Results with yeast and yeast extract in the food were variable.

Sucrose, dextrose, and levulose solutions with either liver broth or liver extract spoiled quickly. The foods containing honey did not spoil so quickly. Since the ants did not eat spoiled foods, the results in the tests using frequently changed food-soaked-cotton, are much better than the results in the artificial nests given the same foods, where unused food could not be removed. Sodium benzoate, sodium propionate, calcium propionate, and citric acid in strengths tolerated by the ants were ineffective in controlling decay and molds.

During 3 years 86 artificial colonies were fed 38 food combinations. Most of these colonies were kept in artificial nests of the usual pattern. The successful completion of larval development indicated by the spinning of a cocoon was used as the criterion in determining which foods contained all essential elements. No colony was able to nourish larvae until pupation on any dilution of honey, beef broth, or liver broth. All successful foods were mixtures of a carbohydrate and a protein. In these tests a colony was given one kind of food for 2 or 3 months. If larvae were not developing satisfactorily, another food was tried. In this way some artificial colonies were given three or four foods during their existence.

Of the seven foods upon which artificial colonies lived and fed larvae until cocoons were spun, all except one had honey as the carbohydrate portion of the food. This colony had one larva spin a cocoon while receiving 12 per cent sucrose in yeast extract with 250 milligrams of liver extract per 100 cc. added. Three times as many artificial colonies produced cocoons when fed 25 per cent honey and a protein as did when fed 50 per cent honey and a protein.

Bits of raw liver, liver broth, liver extract, yeast cells, liver extract and yeast cells, and liver extract and yeast extract were the proteins which gave successful results when fed with 25 per cent honey. In seven colonies larvae spun cocooons when fed 25 per cent honey in liver broth while four were successful on 25 per cent honey containing 250 milligrams of liver extract per 100 cc. Three colonies had larvae complete development when the liver extract factor was doubled. Two of these also received yeast cells. One colony was successful on a combination of liver extract and yeast extract, but since more colonies were successful on liver extract alone, the yeast extract is apparently not essential. The value of yeast cells is doubtful although one colony had one larva spin a cocoon with yeast cells as the only source of protein, other than that in the honey. These studies show that 25 per cent honey in liver broth or 25 per cent honey containing liver extract is a complete food for *Formica exsectoides* but that the ants are able to utilize satisfactorily a variety of foods.

Temperature and humidity were also factors in the length of time artificial colonies lived. Of 34 artificial colonies held at approximately 70° F. 23 lived over 200 days or about 7 months. At the end of 5 months the queens had stopped laying, and the workers did not feed well. Clustering, the usual sign of hibernation, was noted. All of these nests had been started with ants collected from hibernation in November or December and forced into activity by a higher temperature. In 33 artificial nests with temperature varying from 48° to 94° F., seven colonies lived more than 300 days, and three of these survived longer than a year. After being in captivity 306 days, the queen of one colony again began to lay eggs. The eggs hatched, but the larvae did not complete development. This colony was fed 25 per cent honey in liver broth most of its existence. These artificial colonies were started in the winter but were not forced into activity rapidly. In all artificial colonies, the humidity was kept as near that of moist soil as possible and water was given three times a week.

CONTROL.—Poisoned food is used to control some ants, but the habits of *Formica exsectoides*, with their wide variety of food and the wide distribution of the colonies, make posioning difficult.

During the winter of 1943-44 a small colony of these ants, formed by workers and queens that escaped from artificial nests, was tested. These ants foraged over the greenhouse, but the food supply was often limited although 25 per cent honey in liver broth was placed near the mound occasionally. One day an arsenite of soda ant poison was set out instead of the 25 per cent honey in liver broth. The workers fed as usual for several hours and then stopped although plenty of the solution remained and no other food was offered. The next day several hundred dead ants were on the mound. The colony was weakened but not killed as, later, when the colony moved they carried away pupae. For 2 weeks after being fed the poisoned food, these ants ignored any food from the spot used for the poison. It was six weeks before they would touch a sugar-water solution. The poisoned solution was consistently refused regardless of container or place.

This evidence from a colony that did not have adequate food and the unpromising results from field trials with foods, indicate that use of poisoned food is not a satisfactory method of control for these ants.

Fumigation has been tried by a number of workers. Peirson (1922) tried potassium cyanide, corrosive sublimate, carbolic acid, kerosene, gasoline, napthalene, and carbon disulfide in control experiments. Carbon disulfide alone was effective. Manter (1925) found that calcium cyanide was effective. Johnson & Friend (1941) found methyl bromide was more effective than carbon disulfide; rotenone showed promise.

METHYL BROMIDE TESTS.—During the summer of 1944 and the spring of 1945, 31 mounds were treated with methyl bromide. This was injected at points from 6 to 18 inches beneath the top of the mound by means of a special applicator by which exact dosages could be measured in cubic centimeters. Preliminary dosages of 50 and 100 cc. were used on two active colonies. After 2 days the ants were moving about on the mound but were not conducting normal activities. After a week the lower half of the mound was covered by dead ants apparently removed from the mound, but the ants in these two mounds finally succumbed.

The success of the preliminary tests led to the treatment, in the fall of 1944, of 25 mounds in a clearing, in the same manner with dosages varying according to the size and symmetry of the mounds. Examination a month after treatment showed 52 per cent of the colonies were killed by the treatment. By the spring of 1945, 60 per cent were dead, but four more old mounds had been occupied. Retreatment of these and the remaining mounds that showed some active colonies eliminated the major portion of the ants. After a year, ants had again occupied some of the mounds indicating the necessity of control measures in the surrounding woods or continuing treatments at intervals as ants migrated into the clearing. Unsymmetrical mounds, as those with the cone injured by any cause such as by falling trees or by the hoofs of animals, required larger dosages than symmetrical mounds.

PARADICHLOROBENZENE TESTS.—During the fall of 1944 and the spring of 1945, 11 mounds were treated with 4, 8 or 16 ounces of paradichlorobenzene. In only one mound, which was treated with 16 ounces of paradichlorobenzene, was the colony completely eliminated. In the other tests, temporary reduction of activities was apparent; but in time, each treated mound showed resumption of normal activities including repair of the mound or extension to one side and construction there of a normal mound.

TESTS WITH DDT.—Tests were made with 20 per cent DDT in pryophyllite and a few strengths of a DDT emulsion. The emulsion was made by dissolving 20 parts of DDT in 60 parts of xylol and emulsifying with an emulsifier. This emulsion was diluted to the strength of DDT desired.

On May 3, 1944, four mounds were dusted with 20 per cent DDT in pyrophyllite. Two weeks after treatment, activity in these mounds was not greatly changed. One mound was dusted a second time, but activity of the ants remained normal. The others were sprayed with 2 per cent DDT in August. The next spring these three were inactive.

Four mounds were sprayed with 0.4 per cent DDT emulsion. Two weeks later the colonies showed normal activity. Three were retreated with 0.4 per cent DDT. The rest of the summer these colonies showed some activity, but the mounds were not repaired or kept free of growing

plants. The following spring, one showed some activity. The other two were dead.

In April 1945, nine mounds were sprayed. Five of them were sprayed heavily with 0.8 per cent DDT emulsion. Three of these were low mounds in a grass field. A week after treatment, dead ants were present on the mound, but some of the ants were still carrying on the usual activities of the colony. The other two colonies showed no reduction in activity. Four mounds were sprayed with 0.4 per cent DDT. Dead ants were not found on these mounds and after one month no reduction in activity was apparent.

The stronger of the two DDT emulsions destroyed many ants and showed promise, in repeated applications, of being effective in the control of this ant. The weaker dilution was ineffective and two applications of 20 per cent DDT dust were likewise ineffective.

FUMIGATION—Ten colonies were treated in 1945 with a new trade marked soil fumigant[1] at the rate of 50, 100, 200, and 400 cc. per mound. The lower amounts were poured through a pipe having perforations on the side at the pointed end. The 400 cc. dosage was distributed in six separate thrusts of the pipe. The colonies in two small mounds were eradicated by a single treatment of 100 cc. each, and the colony treated with 400 cc. was killed. All other treatments were ineffective.

SODIUM FLUORIDE AND CRYOLITE MIXTURES.—Sodium fluoride tested in the summer of 1946 showed greater promise in the control of this ant than any previously employed chemical and has the advantages of ease of application, availability, and reasonable cost. The fluoride was superior to the cryolite mixtures although one application of the undiluted cryolite gave a decided reduction in activity of the ants.

For these tests 36 mounds were used. Fifteen were treated with sodium fluoride. Eleven of these colonies were killed, and the others showed great reduction in population. The remaining 21 were treated with cryolite compounds. Only one colony was eradicated, and this was treated with a fluorine compound[2] containing sulfur. Five others showed great reduction in numbers. The rest showed little effect of the materials used. An important point seems to be the completeness of the band of material around the periphery of the mound. Dusting the whole mound did not increase the effectiveness of any of the materials.

SUMMARY—Under natural conditions, *Formica exsectoides* colonies are active from April to October. During this time new colonies are established by swarming, winged males and females are developed in numbers and the colony increases in population. Food is the honeydew obtained from honeydew-producing insects found on the trees and the soft parts of insects picked up on the ground.

In artificial nests held at approximately 70° F. eggs required an average of 19.4 days to hatch, larvae completed development in an average of 37.1 days and pupae needed an average of 25.1 days before callows emerged. Two weeks were required for the callows to darken into normal workers.

All foods successfully used for artificial colonies were mixtures of a carbohydrate and a protein. For the carbohydrate portion 25 per cent honey was the most satisfactory. It apparently supplied the carbohydrate and some of the minerals and vitamins necessary since similar strengths of the pure sugars did not enable larvae to complete development. Liver broth, or 250 milligrams of liver extract per 100 cc. of liquid, satisfactorily supplied the rest of the minerals and vitamins as well as the protein.

The most satisfactory control used was the placing of a complete barrier band of sodium fluoride around the periphery of the nest. Fumigation with various materials presented difficulties in application and were only partially effective. Control by poisoned baits was unsatisfactory due to the abundance of natural foods and the discrimination of the ants.

[1] Dow Chemical Co., Midland, Michigan. (*Dow fume G*)

[2] Kryocide Pennsylvania Salt Co. Philadelphia, Pennsylvania.

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Control of the Spruce Mite

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The spruce mite, *Paratetranychus ununguis* Jacobi, frequently becomes troublesome in Ohio during hot, dry seasons. It has been observed most often on arborvitae, spruce, and juniper. At the outset, the foliage of infested trees loses its deep green lustre and later becomes bronzed or rusty. In instances of severe attack, the plants may be defoliated. Young trees or recent transplants may be killed in one season and older trees may be severely injured and become unsightly.

Relatively few publications have appeared which suggest control measures for this pest. The use of dormant oils is sometimes recommended but when applied at a strength that will kill the overwintering eggs, certain species of evergreens, particularly spruces, may be injured. Dormant lime-sulfur is less effective and not very satisfactory.

Superfine sulfur dust has been recommended for use during the summer months. It will greatly reduce a population, but repeated applications must be made to yield control. Also, if applied heavily, it leaves a residue that may be objectionable, and at temperatures above 80° F. burning may result.

Experiments in control of the spruce mite were begun at the Ohio Agricultural Experiment Station during the summer of 1945. At that time, a heavy infestation was observed on a small planting of arborvitae in a nursery at Ghent. A replicated series of experiments was carried on in this planting. The experimental area included 32 trees varying in height from 18 to 36 inches. Each tree was considered as a plot which permitted eight replications of three treatments and an untreated check. The sprays were applied on June 19 with a small power sprayer at a pressure of approximately 225 pounds. Four days later, living and dead mites were counted on twig samples taken from each tree. The data obtained are summarized in table 1.

Although living mites were abundant on the check trees, none was found on the trees that were sprayed with *Dowspray-17*. The Mannitan monolaurate compound also yielded good results. The grower further checked the effectiveness of the materials by holding a white paper beneath a branch of one or more trees in each treatment and then jarring the branch sharply. In that manner he found many living mites on the check trees, but none on the trees sprayed with *Dowspray-17*. Later, he sprayed the remainder of the

Table 1.—Spruce mite mortality on arborvitae 4 days after treatment.

Materials Used	Number Mites Counted	Per Cent Dead
A mannitan monolaurate preparation,[1] 1 part to 400 parts water	168	98.8
A dinitro compound,[2] 12 ounces in 100 gallons	198	100.0
Flotation sulfur paste, 8 pounds in 100 gallons	246	87.4
Check (not treated)	356	3.9

[1] NNOR, a commercial preparation of the Atlas Powder Company, containing 1.0 per cent rotenone, other derris extractives, and mannitan monolaurate.

[2] A commercial preparation of the Dow Chemical Company containing 13.3 per cent dinitro-o-cyclohexylphenol, dicyclohexylamine salt. (*Dowspray-17*)

planting with this material and was well pleased with the results.

In 1946 another series of experiments was carried on in a larger planting of arborvitae in the same nursery.[1]

The experimental area included 150 trees of approximately the same size as those employed in 1945. It was divided into 5-tree plots in order to accommodate five treatments and a check, each replicated five times. Each treatment, therefore, was applied on 25 trees. Four sprays and one dust were tested in an application made June 11. The sprays were applied with the sprayer used in 1945 and the dust with a rotary hand duster. Three days after the materials were applied a sufficient number of twig samples were examined from each plot to yield a total of 100 mites. The data obtained are presented in detail in table 2.

Table 2.—Mortality among 100 mites from each arborvitae plot 3 days after treatment.

Materials Used	Replications 1	2	3	4	5	Average
A chlorophenyl compound,[1] 1 part to 400 parts water	99	100	95	100	96	98.0
Same, 1 part to 300 parts water	100	100	95	99	100	98.8
A chlorophenyl compound,[2] 1 part to 400 parts water	90	93	90	93	97	92.6
Dowspray-17, 12 ounces in 100 gallons	100	100	96	100	99	99.0
A DN dust[3]	84	89	79	92	92	87.2
Check (not treated)	0	0	0	0	0	0

[1] An experimental preparation of the Dow Chemical Company containing 90 per cent 1,1-di(x-chloropheynl) ethane (*C-620*)

[2] An experimental preparation of the Dow Chemical Company similar to *C-620*, containing 98 per cent 1,1-di(x-chlorophenyl ethane (*C-420*).

[3] A commercial preparation of the Dow Chemical Company containing .25 per cent dinitro-o-cyclohexylphenol, dicyclohexylamine salt (*DN-Dust 269*).

[1] This work was done in cooperation with the Dow Chemical Company in order to test new materials. The company provided the materials and paid part of the expenses of the project.

As indicated in table 2, the records obtained were unusually uniform. An analysis of variance indicated that *DN Dust 269* was significantly less effective than *C-620* and *Dowspray-17*. In a similar count made 6 days later, this difference had largely disappeared. All of the materials tested seemed very effective. The results of the two counts are summarized in table 3.

Table 3.—Average mortality of spruce mites on arborvitae after one application.

Materials Used	Per Cent Dead In 3 days	In 9 days
C-620, 1 part to 400 parts water	98	96.4
C-620, 1 part to 300 parts water	98.8	95.6
Cr420, 1 part to 400 parts water	92.6	96.6
Downspray-17, 12 ounces in 100 gallons	99	99.4
DN Dust[1] *269*	87.2	92.8
Check (not treated)	0	6.8

[1] See notes under Table 2.

On June 20 each material was applied a second time on the same series of plots. June 25, spruce mite mortality records were taken for the third time. The data obtained are summarized table 4.

Table 4.—Average spruce mite mortality after two applications.

Materials Used	Per Cent Dead After Second Application
C-620, 1 part to 400 parts water	100
C-620, 1 part to 300 parts water	100
C-420, 1 part to 400 parts water	98.2
Downspray-17, 12 ounces in 100 gallons	100
DN Dust 269	96.4
Check (not treated)	21.4

All materials again yielded excellent results. No living mites were observed on the plants sprayed with *Dowspray-17* or *C-620*. No injury that was caused by the materials was observed, although the *DN Dust 269* left a visible residue that might objectionable in a nursery. The mortality on the untreated trees increased as the season advanced, but the population also increased. On June 25, when the last

mortality record was taken, many of the untreated trees had taken on a rusty brown color and in most cases could be detected without consulting the label stakes.

While the work was in progress at Ghent, a relatively heavy infestation of spruce mites was found on white spruce in a small nursery at Doylestown. The trees in the latter planting were approximately the size of those at Ghent, but several were already injured by mites. Arrangements were made to repeat in this planting the series of tests carried on at Ghent. Plots were arranged in the same manner, using five replications of each materials on five-tree plots. The materials were applied on June 26 and counts were made 3 days later. The data obtained are summarized in table 5.

Table 5.—Average mortality of spruce mites on white spruce 3 days after treatment.

MATERIALS USED	PER CENT DEAD
C-620, 1 part to 400 parts water	86.2
C-620, 1 part to 300 parts water	96.8
C-420, 1 part to 400 parts water	91.4
Downspray-17, 12 ounces per 100 gallons	98.5
DN Dust 269	98.3
Check (not treated)	14.2

Each material again yielded excellent results. *DN Dust 269* seemed somewhat more effective on spruce than on arborvitae. It seems probable that this was due to the more resinous nature of the white spruce twigs which caused the dust to adhere more effectively.

One week after the experimental treatments were applied, the entire block, which contained about 500 trees, was divided into three sections. Each was treated with one of the three most promising materials used in the experimental setup. Counts were made 5 days later by counting living and dead mites on samples taken at random in each plot until approximately 300 mites were counted. The data obtained are summarized table 6.

Table 6.—Average spruce mite mortality on white spruce 5 days after treatment.

MATERIALS USED	PER CENT DEAD
C-620, 1 part to 300 parts water	94.4
Downspray-17, 12 ounces in 100 gallons	99.7
DN Dust 269	100.0

As indicated in the table, no living mites were observed on the samples examined from the dusted area and only one was seen on those from the area sprayed with *Dowspray-17*. Some of the plants that had been sprayed on June 26 appeared to be recovering from the spruce mite injury.

SUMMARY—When conifers were sprayed with *Dowspray-17* at the rate of 12 ounces in 100 gallons of water, the average spruce mite mortality in six tests was 99.4 per cent. Three of these records were taken within 5 days after a single application, one was taken 9 days after a single application and two were taken 5 days after a second application had been made.

Four other materials were tested that yielded good results. (1) *DN Dust 269* leaves a visible residue, but should prove satisfactory where such a residue is not objectionable. (2) *NNOR* was used in one test only. Nos. (3) and (4) *C-420* and *C-620* are experimental materials and at present are not on the market.

Finally, it may be said that this work resulted in finding three materials now available which give good control of the spruce mite and, in addition, two new experimental materials were used that show definite promise.

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SCIENTIFIC NOTES

Control of the Tomato Fruitworm in 1946

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For a number of years, experiments have been conducted by the Department of Entomology of the Louisiana Agricultural Experiment Station to test the effectiveness of various insecticides on control of the tomato fruitworm, *Heliothis armigera* (Hbn.), infesting tomatoes.

Past experiments have been concerned with the combination of a fungicide or several fungicides with the insecticides being tested. Fungicides used were usually of the fixed copper group. Under this setup, all plots in the experiment did not necessarily receive the same fungicide, and some plots received no fungicidal treatment. Insecticides tested were those commonly used, as well as new ones entering the field in an experimental manner. The arsenicals (lead and calcium arsenates), cryolite in various dilutions, DDT, and benzene hexachloride were among those tested.

The growing of fall tomatoes is a delicate problem in Louisiana and is not always successful. As a rule, the fruitworm is a more serious pest at this time than in the spring. This is perhaps due in part to the absence of corn to entice moths away from the tomato field at this season of the year. It is generally conceded by entomologists that tomato fruitworm infestations in spring-grown tomatoes drop rapidly when corn begins to silk.

The experiment on fall tomatoes in 1946 differed from previous tests in that fungicides were eliminated from all of the insecticides. The entire field was treated for disease control but the applications were made independent of the insecticides. The fungicide treatment consisted of alternate applications of tetra copper-calcium oxychloride,[1] containing 5 per cent metallic copper, and zinc dimethyldithiocarbamate.[2] Two applications of each were made, beginning in the pre-bloom stage.

A field approximately 0.75 acre in area that had been planted in mid-July to the Louisiana Red variety was used in the experiment. The plants were spaced 2 feet in the row and the rows were 46 inches apart. Normal recommended practices of culture were followed, and the plants were staked and kept tied. The field was laid off in a 5×5 latin square, each plot being 55 feet long and 23 feet wide and containing 6 rows with a total of 165 plants. The area of each plot was .029 acre. At the ends of each plot was a 10-foot buffer space unplanted.

The following insecticides were used in this experiment:

1. DDT—3%
2. Chlordane[3]—2%
3. Cryolite—95% (Synthetic), containing 5% conditioner
4. Calcium arsenate
5. Check (no treatment)

A diluent[4] was used in the DDT. The same material was used as the conditioner in the cryolite.

APPLICATIONS.—The plan of the experiment was to make the first application at the time the fruit on the first cluster began to form and to make subsequent applications at weekly intervals until the first fruit matured or showed signs of ripening. This schedule was adhered to as nearly as possible. However, application No. 1 should have been made two or three days earlier because at this time some of the fruit was marble size.

Applications were made in the mornings with handguns, the operator applying the dust but once to the row. However, an effort was made to cover as much as possible of the plant surface by moving the nozzle up and down. Every application was made under adverse weather conditions, so far as wind velocity was concerned. However, no application was washed off by rain under 48 hours. A total of five applications was made at an average of 7-day intervals. The dusting dates were as follows: September 13, 19, 24, October 3 and 10. An effort was made to apply the dusts as uniformly as possible; however, in order to secure proper coverage the rate per acre varied between some of the treatments, owing to differences in density and other physical properties of the insecticides. The last application was made on the date of the first harvest of fruit.

RECORDS.—The two center rows of each plot were

[1] *Copper A.*
[2] *Zerlate.*
[3] *Velsicol 1068.*
[4] *Attaclay.*

Table 1.—Showing treatment yields with statistical analysis.

TREATMENT	AVERAGE RATE PER ACRE	PLOT YIELDS		WORMY FRUIT*	INCREASE OVER CHECK	
		Sound	Wormy		Sound Fruit per Acre**	LOSS PER ACRE FROM WORMS**
	Pounds	*Number*	*Number*	*Per Cent*	*Pounds*	*Pounds*
DDT—3%	25.5	3476	70	1.97	4016	389
Velsicol—(1068) 2%	28.8	3067	445	12.66	1618	2490
Cryolite	22.2	3675	109	2.87	5134	664
Calcium Arsenate	15.3	3057	229	6.96	1668	1280
Check		2759	746	21.28		4177
Minimum difference required for significance				3.37		

* Based on number of fruit.
** Based on average weight per fruit.

used as record rows. These two rows contained an average of 55 plants. When there was a missing plant in one of the record rows, the plant opposite in the adjacent row was substituted. The fruit was harvested just as the color began to show pink. Ten harvests were made at approximately 3-day intervals. Immediately following a harvest the fruit was examined and graded into two classes: wormy and sound. The total number of fruits in both classifications was recorded, and the combined weights of both groups taken. The weights from all plots were combined and an average weight per fruit was determined.[5] From this figure the yield in pounds per acre was calculated. Table 1 shows the differences in worm infestation by treatments with statistical analysis, and calculated increased yields of sound fruit per acre by treatments.

DISCUSSION OF RESULTS.—DDT gave a control of the worms representing less than a 2 per cent loss, while the check suffered over a 20 per cent loss. Cryolite ranked second to DDT with less than a 3 per cent loss, while calcium arsenate and chlordane suffered approximately 6 per cent and 12 per cent injury, respectively. Calculated yields on the acre basis showed that in the check there was a yield of 15,457 pounds of worm-free fruit as compared to 19,473 pounds and 20,591 pounds for the DDT and cryolite treatments, respectively. This represents a significant increase in yield of approximately 20 to 25 per cent. The chlordane and calcium arsenate plots produced 17,179 and 17,125 pounds, respectively, of worm-free fruit per acre. Analysis of variance, based on numbers of fruit attacked, showed that all treatments resulted in significant control over the check; however, both DDT and cryolite were significant over calcium arsenate and chlordane. There was no difference in control between cryolite and DDT.

SUMMARY.—An experiment conducted for the control of the tomato fruitworm on fall-grown tomatoes is reported. The plots were arranged in a 5×5 Latin square. The methods of treatment and sampling employed are described.

Results of this experiment are as follows: DDT, 2 per cent fruit wormy; cryolite, 2.8 per cent; chlordane, 12.6 per cent; calcium arsenate, 7 per cent; and check, 21 per cent of fruit wormy. All treatments were significant over the check in controlling the fruitworm; however, DDT and cryolite were significant over all other treatments. There was no difference between DDT and cryolite.

The increase by treatments of sound fruit per acre is as follows: DDT, 4016 pounds; cryolite, 5134 pounds; chlordane, 1618 pounds; calcium arsenate, 1668 pounds. The check yielded 15,456 pounds of worm-free fruit.—2-7-47.

[5] This figure is 4.34 ounces.

Liquefied Gas Aerosols for Control of Insects on Eggplant and Broccoli[1]

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Preliminary experiments on control of the eggplant lace bug *Gargaphia solani* Heid. with DDT aerosols were carried out in 1944 (Smith *et al.* 1945) and repeated on a more extensive scale in 1945 (Owens & Ditman 1946). In 1946 approximately six-tenths of an acre of eggplant was made available on the same farm where the 1945 tests were conducted. This field contained 1991 plants which had been set in late May. Except for two untreated check rows the plants received weekly aerosol treatments, beginning on June 8 and ending August 23. The first treatment was applied with a knapsack type dispenser equipped with a single nozzle; the succeeding treatments were applied with a single row hand drawn dispenser equipped with a 6 ft. muslin apron. This machine in the second, third, and fourth treatments was used with one nozzle directed downward; in succeeding treatments with four nozzles, two on each side of the row, directed inward. The aerosol solution contained 50 per cent *Freon 12*, 5 per cent DDT, 5 per cent cyclohexanone, 5 per cent *Velsicol AR60* and 35 per cent acetone. The amounts per application varied from 2 pounds 8 ounces on July 1 to 12 pounds 6 ounces on August 12. A total of 81 pounds 13 ounces liquefied gas solution was used, averaging about 8 pounds 3 ounces per application.

Population records based on counts of 50 plant samples taken at random were kept on flea beetles, no attempt having been made to segregate species, the eggplant lace bug, and the margined blister beetle *Epicauta solani* Werner; they appear in table 1. In studying table 1, it will be observed that the heaviest movement of eggplant lace bug to the treated plants occurred between June 29 and July 15, while on check plants the adult lace bug population remained rather constant until after the last treatment. That there was considerable reduction of lace bugs in the check row caused by insecticidal drift is shown by the reduction of check populations after treatment and by the rapid build-up of the adult population of the check plants 11 and 24 days after treatments were discontinued. There was apparently sufficient residue on treated plants to regard the build-up of infestation at least 24 days after treatments were discontinued. The effectiveness of the treatment on eggplant lace bug is further emphasized by the almost complete reduction of nymph masses.

Flea beetles began to migrate to young plants as soon as set, the heaviest period of migration according to table 1 occurring during July. The large number of flea beetles per plant during July may not, however, be caused so much by a greater number of migrating beetles in the area at this time as by the ability of larger plants to support larger populations. The flea beetle population in the check rows was not affected as much as the eggplant lace bug by insecticidal drift.

Eggplant shows a marked growth response when protected from insects by efficient insecticidal treatment. A total of 293 bushels of fruit was harvested with an average production of .155 bushel per treated plant as compared with an average of only .024 bushel per plant in the untreated portion of the field.

Approximately an acre of broccoli located near Cambridge was made available by the Trappe Canning Co. for exploratory work with aerosols. The field was divided into five blocks, each containing four plots of three rows each. A single plot in each block was used as check; the other three received treatments as follows: application every week, every 2 weeks, and when required by evident increase in infestation. An aerosol of the formulation used on eggplant was applied with a similar machine equipped with four nozzles. Treatments were begun on July

[1] Richmond Program Paper.

Table 1.—Summary of insect populations on treated and untreated egg plants throughout the season.

Date	Eggplant Adults			Lacebug Masses of Nymphs			Flea Beetles			Blister Beetles	
	Population		Reduction per cent of check	Population		Reduction per cent of check	Population		Reduction per cent of check	Population	
	Treated	Check		Treated	Check		Treated	Check		Treated	Check
June 17[1]	0	5		0	0		0	55		0	0
19	0	2	100	0	1	100	3	70	96	0	0
25	1	4		0	2		33	69		0	0
26[1]	4	3		0	2		41	75		0	0
29	19	31	39	0	1	100	36	91	60	0	0
July 1	25	68		0	2		82	122		0	0
3	5	33	85	0	0	—	57	243	76	0	0
8[1]	34	47		0	1		247	448		0	0
10	3	52	94	0	1	100	31	490	94	0	0
15[1]	58	62		4	28		287	709		0	0
17	0	33	100	0	0	—	10	844	99	0	0
22[1]	4	9		0	2		28	875		0	0
24	1	17	94	0	0	—	19	998	99	0	0
29[1]	2	21		0	3		93	788		0	0
31	1	30	97	0	10	100	0	689	100	0	0
Aug. 5[1]	8	42		0	11		31	301		0	0
7	0	17	100	0	5	100	0	149	100	0	0
12	1	53		0	3		41	260		0	27
14	0	13	100	0	2	100	1	61		0	0
19	5	90		0	27		84	562		0	5
23[1]	9	57	84	0	42	100	102	347	71	1	57
Sept. 3	6	229		0	80		115	254		0	22
16	10	458	98	7	144	95	83	711	88	0	2

[1] Counts made immediately before treatment.

Table 2.—Summary of insect population on treated and untreated broccoli throughout the season. Cabbage Worm populations are based on actual number of such insects. Aphid populations are based on the number of plants serving as hosts for either light or medium infestations.

Date	Population of Cabbage Worms				Population of Aphids							
					Treated Weekly		Treated Every 2 weeks		Treated When Needed		Check	
	Treated Weekly	Treated Every 2 weeks	Treated When Needed	Check	Medium	Light	Medium	Light	Medium	Light	Medium	Light
June 28[1]	4	2[1]	5[1]	2		11		4		11		6
30	1	2	5	0		1		4		11		1
July 3[1]	0	0	0	0		6		5		7		3
6	0	0	0	3		0		0		0		1
11[1]	32	44[1]	32[1]	103		16		20		20		18
13	1	3	1	8		11		17		14		14
18[1]	9	21	14	76		24		23		15		34
20	2	17	33	55		8		16		18		23
25[1]	7	117[1]	113[1]	148		13		11		15		24
27	0	0	0	8		6		5		9		22
Aug. 1[1]	14	20	16	92		16		18	1	16	1	23
3	0	24	25	117		6		15		23	1	29
8[1]	11	54[1]	95[1]	120	1	14		10	1	16	1	10
10	1	2	3	48		3		7		6		15
15[1]	0	5	15	96		11	1	15		14	2	19
17	0	4	17	134		10		11	1	24		26
22[1]	21	95[1]	94[1]	225		18	1	40		37	2	31
Sept. 2	6	1	4	68	1	27		30	1	34	5	42

[1] Counts made immediately before treatment.

[1] Counts made immediately before treatment.

3 and continued through August 22. Population records were kept collectively on the two cabbage worms *Pieris rapae* (L.) and *Trichoplusia ni* (Hbn.) and on the cabbage aphid *Brevicoryne brassicae* (L.).

The results are given in table 2. Examination of the table shows that the DDT aerosol was highly effective against the two species of cabbage worms and that the insecticidal drift greatly reduced infestations in the check plots. The treatments reduced the aphid infestation, but there was apparently a rapid build-up after treatment. There was no growth response following treatments as in the case of eggplant, the plants in check plots being just as vigorous as those which had received treatment.—12-19-46.

Fly Control in Dairy Barns and on Livestock by Cooperative Spray Services[1, 2]

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During 1944 and 1945 the writers investigated the effectiveness of DDT in various forms and formulations as a barn and livestock spray for the control of flies. Work was done on over 100 farms. The results obtained were so satisfactory on the whole that those farm leaders familiar with the work expressed a desire for the establishment of cooperative services whereby farm people could obtain effective and efficient work on an economical basis.

Beginning in the early winter of 1946, cooperative programs were encouraged in six counties. These counties were for the most part located in those areas where dairy interests are important. In all of the counties with the exception of one, the cooperative arrangement was between the Entomology Department of the University of Maryland, the County Farm Bureau, and the County Agricultural Agent. In the operation of the programs, the Department of Entomology at the University prescribed the materials, the dosages, methods of application, and made observations on results obtained. The County Farm Bureau furnished the equipment, hired the help and paid the bills, while the local extension office supervised the technique of applying the material and assisted in recording and analyzing the results. In one county the work was maintained on an experimental and demonstrational basis, and the county commissioners cooperated in financing the work.

The outlines drafted by the Department of Entomology called for the participation of a minimum of 100 farmers in each county to accept three applications of spray at a total cost for all applications, not to exceed $30.00 for a 50-cow dairy barn. The estimated cost for spray equipment was $2000 and it was to be amortized over a period of three years. The soundness of the plan was demonstrated by the fact that the demand for service was over-subscribed, all equipment was paid for during the summer and the cost for service was on the average less than the estimate. In one county two additional machines were purchased in 1946, to meet current demands. Additional equipment will be purchased in 1947, because the services rendered thus far have created a demand from practically every farm for inclusion in future plans.

The work on fly control involved the use of 95,500 gallons of material in spraying 3584 farm buildings and 18,155 farm animals, mostly dairy cows. DDT wettable powder was used throughout the demonstrations at the rate of 1 per cent of actual DDT for all the barn spraying. At the onset 0.25 per cent DDT was used on the first herds, but it was soon determined that it was more economical to use the same strength in spraying animals that was being used for the barns, as the saving in material was more than offset by the extra labor in change over in the field. Pressure of 400 to 500 lbs. was used in most of the work, as such pressure atomized the spray efficiently, drove it into all cracks, and crevices, and was especially efficient in the treatment of animals, insuring the most lasting effectiveness.

The costs varied somewhat in the several counties due to different bases for charges. Some counties had service charges plus 17 cents per square foot of wall surface. Some counties charged on the basis of the number of gallons used. The charges varied from 15 to 20 cents per gallon. Charges were also based upon a unit price of 20 cents per stanchion in some dairy barn operations. The cost per barn varied from approximately $6.00 to $10.00 per application for a 50-stanchion barn. In one county the average cost per building based on an approximately average size of barns of 36′×50′×10′ was $3.16 per application. The cost for spraying animals varied from 5 cents per calf to 10 cents per yearling or older animals. Other animals such as hogs were often sprayed but no separate schedules were set up in such cases.

The results obtained in fly control were outstanding in barns and on animals. In barns the lasting qualities of the spray varied from 6 to 15 weeks with 10 weeks representing a fair average. In all instances three applications proved effective for the entire season; in most cases two applications were all that were needed, and in some cases one application was sufficient. The lasting qualities of the spray seemed to be best in barns with a rough wall surface unless the surface was coated with dust at the time of application. In such cases the residue seemed to flake off with the dust.

Excellent results were obtained by spraying animals. Sprayed animals in general were freed of flies. They remained much quieter, and stayed in the open, grazing peacefully. Numerous dairymen reported increased milk production; normally they expect a decrease in production during fly season.

Sprayed animals were protected for periods of from 3 to 6 weeks unless subjected to heavy rainfall. Sprays applied with power equipment gave protection to animals for much longer periods than those applied with hand equipment. Material applied under pressure of from 400 to 500 lbs. often lasted up to 6 weeks, whereas with low pressure, and in particular with hand sprayers, the period of protection decreased to as short as 5 days.

At the beginning there was considerable skepticism on the part of many farmers, but enthusiasm for the work gained momentum as the season progressed. Fear was expressed by many dairymen as to the possibilities of injury to their animals and the influence of the spray on dairy scores. No adverse effect on cows was discernible and dairy scores were not reduced. Late in the summer dairy inspectors did not insist on the maintenance of screening.

The combination of spraying both buildings and animals practically eliminated flies as a nuisance on premises so treated. On dairy farms where only the buildings were sprayed, many flies would come in each morning and evening with the animals. Where the animals were sprayed along with the buildings, this did not occur.

At the end of the fly season surveys were made to obtain the reaction of the farmers on the value and effectiveness of the program. The farmers who used the service on the whole felt that the service provided better results at a lower cost than could be obtained with the hand equipment ordinarily in use on the farm. Only 5.2 per cent of the farmers surveyed felt that they could provide for themselves equal results with the same degree of economy. Practically every farmer using the service was enthusiastic about the results.

The success of the fly program led to a demand for

[1] The supervision of the cooperative programs and the collection of the data was the function of the following county agricultural agents: O. W. Anderson, H. W. Biggs, L. C. Burns, H. B. Derrick, H. M. Carroll, J. W. Eby, and W. G. Myers.

[2] Richmond Program Paper.

other work, such as the control of mosquitoes, lice, and Japanese beetles. Actually any project of general public concern *is* susceptible of attack by this method of cooperative services.

BENZENE HEXACHLORIDE AS A BARN AND CATTLE SPRAY.—In connection with the fly control work outlined benzene hexachloride was tested rather extensively as a barn and animal spray. Because of the odor of this material, all work was confined to animals and buildings other than those associated with dairying.

The material used was a 50 per cent wettable powder prepared from material containing 10 per cent of the gamma isomer. This material was compared pound for pound with DDT. Excellent results were obtained in all tests. Fly knockdown was more rapid than with DDT and residual action in barns and on animals seemed to be just about as effective and lasting. In several instances the lasting qualities seemed to be better for DDT than for benzene hexachloride. However, the variations in lasting qualities were equally as variable among barns sprayed with DDT. Where herds of animals were divided and sprayed no differences were noted, hence the variations may not be significant.

SUMMARY.—It has been demonstrated to the satisfaction of the county agricultural agents and to the Department of Entomology that cooperative spraying services for the control of flies on farms can be accomplished efficiently and economically when an adequate number of high powered spraying outfits are available and well thought out plans of operation, especially advance scheduling and routing are prepared. Cooperative groups such as the farm bureaus are desirable as sponsoring agencies since they represent the majority of the farmers and are in a position to finance the initial costs, which can be amortized even at the present low unit costs. The virtual elimination of flies from sprayed premises means much in comfort, increased production, and protection of health.—1-15-47.

Pre-treating House Flies with Synergists Before Applying Pyrethrum Sprays[1]

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It has been known for several years that certain chemicals, when added to pyrethrum, increase the knock-down and mortality of insects. Eagleson (1940, 1942) and Haller *et al.* (1942) reported on the effect of sesame oil on the insecticidal action of pyrethrum against house flies. Bushland *et al.* (1944) found that the toxicity of pyrethrum against the human body louse, *Pediculus humanus corporis* Deg., could be increased approximately 100 times by adding N-isobutylundecylenamide. Several other chemicals were found to be effective on flies and mosquitoes at the Orlando, Florida, laboratory of the Bureau of Entomology and Plant Quarantine.

Since no previous work has been done on the pretreatment of insects—that is, exposing them to a synergist first and then to pyrethrum, or vice versa—it is the purpose of this paper to compare this type of treatment with the usual treatments in which the two materials are applied separately or as a mixture.

METHODS.—Small screen-wire cages containing laboratory-reared house flies 4 days old were exposed to misty sprays in a 100 cubic foot testing chamber by a pendulum method (Lindquist *et al.* 1946). One group of flies was exposed to a spray containing 5 per cent of the synergist dissolved in cyclohexanone, and at intervals thereafter separate lots of these flies were subjected to a spray containing 0.1 per cent of pyrethrins (the active principle of pyrethrum in kerosene). Another group of flies was exposed to the pyrethrum solution first and then to the synergist at intervals. Other tests were made in which the pyrethrum and synergist solutions were applied alone and in mixture. "Piperonyl cyclohexenone"[2] was used at a dosage of 0.5 ml. per chamber and sesame oil concentrate and N-isobutylundecylenamide at 0.7 ml. The dosage of pyrethrins in each treatment was the same as that of the synergist. Each test was replicated 6 to 12 times, using approximately 60 flies per exposure. Knock-down counts were taken at 10, 30, and 60 minutes. Mortality counts were taken at 24 hours, but are not included in this paper because they were all very low.

RESULTS.—Table 1 shows that a greater knock-down of house flies resulted when sesame oil concentrate and "piperonyl cyclohexenone" were applied first, followed in 30 seconds by pyrethrum, than when the reverse procedure was followed. This was not true with N-isobutylundecylenamide. A high knock-down resulted when the pyrethrum treatment was applied 1, 2, and 4 hours after the synergists. The 1-hour delayed treatment appeared to be especially effective with sesame oil concentrate and "piperonyl cyclohexenone." The knock-down at 60 minutes diminished progressively with the increased delay of exposure to pyrethrum with the sesame oil concentrate and N-isobutylundecylenamide.

In a supplementary test in which the pyrethrum was applied 1, 7, 24, 48, and 72 hours after the sesame oil concentrate, the 10-minute knock-down was as satisfactory at 24 hours as it was at 1 hour, but little knock-down occurred at 48 and 72 hours.

When the pyrethrum was applied as the initial treatment, followed by the synergists at 1, 2, and 4 hours, the knock-down was nearly zero in all the tests. This suggests that the effect of the pyrethrum on the insects is slight and of short duration. The relative instability of pyrethrum may also be a factor.

In all these tests the flies showed no symptoms of injury after treatment with any of the synergists when they were used alone. The flies fed and reacted normally for several days after treatment. These results suggest that they synergist may cause slight injury or disarrangement to nerve or other tissue, so that pyrethrum applied later is highly effective in producing knock-down. The synergist may also have an effect on the absorption of the toxicant through the cuticle of the insect.

A comparison of the knock-down produced by the synergist-pyrethrum mixture and by the synergist followed by the pyrethrum applied singly (synergist first), shows that with "piperonyl cyclohexenone" the mixture is somewhat less effective than the separate treatments, but with sesame oil concentrate and N-isobutylundecylenamide the two methods are equally effective.

A series of tests was made using DDT instead of

[1] This work was conducted under a transfer of funds from the Office of the Surgeon General, U. S. Army, to the Bureau of Entomology and Plant Quarantine.

[2] This name refers to a commercial product containing a mixture of certain derivatives of piperonyl cyclohexenone but not the piperonyl cyclohexenone itself.

Table 1.—Effect on house flies of spraying pyrethrum and synergist separately and in combination.

TREATMENT	TIME BETWEEN TREATMENTS	PER CENT KNOCK-DOWN IN—		
		10 Minutes	30 Minutes	60 Minutes
Synergist followed by pyrethrum:				
Sesame oil concentrate	30 seconds	71	76	55
	1 hour	95	81	48
	2 hours	73	61	32
	4 hours	77	58	21
"Piperonyl cyclohexone"	30 seconds	76	82	66
	1 hour	86	75	43
	2 hours	83	84	54
	4 hours	85	83	56
N-Isobutylundecylenamide	30 seconds	40	48	28
	1 hour	77	52	14
	2 hours	54	23	4
	4 hours	39	12	8
Pyrethrum followed by synergist:				
Sesame oil concentrate	30 seconds	53	75	44
	1 hour	0	0	0
	2 hours	0	0	0
	4 hours	2	2	2
"Piperonyl cyclohexenone"	30 seconds	37	61	35
	1 hour	0	0	0
	2 hours	0	0	0
	4 hours	0	0	0
N-Isobutylundecylenamide	30 seconds	38	23	26
	1 hour	0	0	0
	2 hours	0	0	0
	4 hours	0	0	0
Synergist-pyrethrum mixture:				
Sesame oil concentrate		65	69	54
"Piperonyl cyclohexenone"		55	78	62
N-Isobutylundecylenamide		40	46	25
Pyrethrum alone (0.5 ml.)		5	2	.3
(0.7 ml.)		9.5	3	.5

pyrethrum with intervals between treatments of 30 seconds and 1 hour. The synergists did not increase the knock-down of the insecticide, whether applied as the initial treatment or the secondary treatment. Neither were there any significant differences in the 24-hour mortalities, except that the mortality was lower when N-isobutylundecylenamide was applied as an initial treatment followed in 1 hour by the DDT treatment. It is apparent that none of these chemicals increases the effectiveness of DDT as it does with pyrethrum.—1-10-47.

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Mirid Damage to Rye

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Leaf spotting and blotching have frequently been observed in Utah in grasses on which mirid bugs were present in varying abundance.

A letter from Dr. George R. Hill, Director of the Department of Agriculture, American Smelting and Refining Company, under date of May 14, 1946, called the writer's attention to nymphal bugs and spotted leaves of rye, collected in Tooele County near Lake Point, Utah. He stated: "It is causing such discoloration to the rye that it is either very much more prevalent this year than last or is some-

thing new, because the boys have inspected these fields in which that volunteer rye is growing, rather carefully in the past." A few mirid nymphs and damaged rye leaves also were received with the letter.

The above fields were carefully checked on May 18, 1946, with large numbers of adult and fewer nymphal *Miris ferrugatus* Fallen being present in several areas of Lake Point on volunteer rye, and on the edges of some rye fields at Erda and northwest of Tooele. Smaller numbers of this species, which was the one sent in by Dr. Hill, generally were present on rye, giant ryegrass, and on certain of the other grasses on nearby uncultivated range land. Leaf blotching, such as was present on samples sent in by Dr. Hill, was common wherever this rather large mirid bug was present. It appeared that the damage was due to this pest which seemed to have some tendency to be gregarius. The bleached out spots tended to become elongate, giving a broken-up blotched appearance to seriously affected leaves.

A smaller mirid, *Trigonotylus ruficornis* (Geoff.) was taken in moderate abundance in several places where insect net sweepings were made to collect the larger bug. In addition, one specimen of *Melanotrichus coagulatus* (Uhler), and several *Dikraneura carneola* (Stal) leafhoppers were taken in these Lake Point collections.

Miris ferrugatus has been collected by the writer on grass in many localities throughout much of Utah, often in moderate abundance. At times it has been encountered on native and introduced range grasses in considerable numbers, as a rule being abundant only on restricted areas, associated with the above broken-spotted leaf condition. This bug has been collected in Utah on wheat, barley and oats, and apparently feeds on a large number of species of the grass family, including the common small grains.—1-5-47.

The Little Fire Ant as a House Pest

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Apparently almost nothing has been published about the little fire ant, *Wasmannia auropunctata* (Roger) ant as a pest in houses. It has become rather serious however in connection with citrus trees as it is often very abundant on them feeding on the honeydew produced on them by aphids and whiteflies and stinging the pickers who gather the fruit. This condition has been quite fully described by Spencer[1] who states that fruit pickers often object to working where the ants are abundant because they sting them so freely.

This ant was first reported from the United States in 1929 in Southern Florida. Since then it has gradually spread northward until it is now present in nearly all of the peninsular portion of the state.

Spencer states that honeydew is probably the most important food of the ants but feeding tests indicate that they will also eat dry sugar, sweet syrups and show a special fondness for cooked fat meats and vegetable oils.

In houses the writer has not found the ants interested in sweet materials but are attracted to most fats, peanut butter and to other fatty or oily material, not visiting sweet substances. To reach such materials they will often travel more than 20 feet. A small bit of mutton fat placed at an inner corner of a desk which extended 4 feet to a window sill was found covered with the ants only 3 hours after it was placed there. Tracing their line of march back it followed the length of the desk to its other end, then crossed the space between the desk and a window sill by means of a telephone cord, a distance of about 6 inches, then trailed along the sill about 2 feet to the corner of a window under which the trail continued to the outer edge of the sill, down and around this to the outside boarding of the house, then down nearly four feet to a place where there was a tiny crevice between the end of a clapboard and a brick chimney. Here the ants entered and were lost to sight, the whole length of the trail being about 17 feet. Lines of ants coming and going were quite continuous and remained so all one afternoon and evening at least. The following morning however the procession had ended.

On many occasions one end of a porcelain sink became so densely covered with the ants that almost no trace of the white porcelain could be seen soon after dark and remained so nearly all night with trails to and from the sink plainly evident. Elsewhere in the house a few ants might be found at almost any time—probably scouts seeking food. Fortunately during the summers none appeared in the beds.

These ants are sensitive to cold and do not appear in spring until the weather has become quite warm, even at night, and disappear with the first touch of cool weather in the fall though if this is followed by a brief period of warm weather they may reappear for a short time.

The worker ants are very tiny—not more than about one sixteenth of an inch long—and the general color of a group is dark gray, though under a lens the red of the body becomes evident. They do not seem to form definite nests underground but clusters of them may sometimes be found under bricks and stones partly covered by earth or grass. More often these clusters occur in cracks or crevices; under pieces of wood or even under dead leaves or rubbish on the ground. Such clusters often appear to be connected with others near by and these conditions seem to imply a colony divided into two or more foci.

The queens are about one-fourth of a inch long (Spencer), The writer himself has never chanced to see a queen although he has examined large numbers of workers gathered for feeding and on the trails between their food and their foci.

Control of this pest in houses is a different problem from that with most ants. With no definite nests where the queens are located there is no central area to attack and it does not appear that supplying the workers with poisoned food to take to the queens is very effective. The workers themselves can be destroyed easily by spraying them and the paths they travel with DDT in such strength as is available at the stores, or by spraying these places with kerosene, *Flit* or numerous other such materials. But after about 10 days to 3 weeks following such a treatment the ants return and resume their visits to any fatty material which may be placed there or still may be present. Constant watchfulness and treatment to destroy the workers when they appear, often using fatty baits to draw them there seems at present to be the only control method available.—1-3-47.

[1] Spencer, Herbert, 1941. The small fire ant *Wasmannia* in Citrus groves—A preliminary report, Florida Entomologist, 24 (1): 6–14.

Control of Black Scale on Gardenias in Commercial Greenhouses

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The black scale, *Saisettia oleae*, a native of tropical and subtropical regions, occurs on many types of trees and shrubs and is one of the most serious insect pests of citrus fruits. In Massachusetts and other northern areas, it is almost entirely a pest of greenhouse plants.

This scale is so prolific and has such a wide range of plants upon which it will thrive that it is always a dangerous pest and, when well established has proved very difficult to control.

It has been estimated that each female may produce more than 2000 young. Egg-laying usually occurs over several months and the appearance of young scales extends over a corresponding period. Repeated applications, at short intervals, of the common types of contact sprays are necessary, over the period when crawling young are present. In cases of serious outbreaks in large greenhouses, this involves heavy cost in labor and materials and in many instances the grower has found himself, in spite of his best efforts, fighting a losing battle because of the brief period of protection furnished by the sprays.

Aside from the direct damage from its feeding, the honeydew excreted by the scales serves as an excellent medium for the growth of sooty fungus. On many greenhouse crops such accummulation of black, sooty fungus on the foliage represents a depreciation in value second only to that caused by reduction of bloom. All these factors combine to make this species one to be dreaded by all commercial growers who encounter it in their houses.

On September 16, the attention of the writers was called to a serious outbreak of black scale on gardenias in a commercial greenhouse. The infestation occurred in both sections of one range, comprising a total of 60,000 square feet. The plants were in their second year of growth and were coming into their first season of full production.

Scale was present throughout both houses but the heaviest attack was centered in the three south benches of the east house. On many plants both buds and leaves were heavily infested and much of the foliage was coated with sooty fungus.

Examination of sample leaves from the southeast section of the house showed an average of 56.5 crawling young and 54.8 older stage scales per leaf or a total of 111.3 scales per leaf.

On this same date a 25 foot section of one bench in the area of heaviest infestation was given a spray of a 25 per cent DDT emulsion at 1:250 dilution. *Volck* (miscible type) at dilution of 3 qts. in 100 gals. was applied to a similar section of the adjoining bench. The rest of the eastern half of the house was sprayed with nicotine sulfate 1:500+fish oil soap 4 lbs. per 100 gal. on September 17, 24, and at 7 to 10 day intervals thereafter.

Results are shown in table 1.

Both houses, except for the two small sections of benches given DDT and *Volck* on September 16, were given nicotine sulfate+soap application at 7 to 10 day intervals.

On October 30 the entire east half of the house was sprayed with DDT emulsion at same concentration as on September 16. *Volck* was omitted because the grower was unable to procure the miscible form used in the first application. The results of this application, from data taken December 11 are shown in table 2.

Table 2.—Results of treatments on October 30.

DATE	TREATMENT	AVERAGE NUMBER OF DEAD SCALES PER LEAF	
Dec. 11	DDT—1 application	148.8	Leaves and buds covered with dead scales. Some older stage scales still alive
	DDT—2 applications	1.6	New growth and buds practically free from scale
	Volck followed by DDT	2.6	

As noted above, most of this house had, previous to October 30, received only a program of nicotine sulfate+soap. Leaves and buds had become heavily infested, which will explain the large number of dead scales on the sample leaves from those sections of the house. The small number of scales from plants in the sections which had been sprayed with DDT or with *Volck* on September 16 indicates how completely the pest had been checked in those benches. Both leaves and buds were practically clear of scale. The new, terminal growth was noticeably greater in these

Table 1.—Results of spray treatments.

DATE	TREATMENT	CRAWLING YOUNG	OLDER STAGES	TOTAL
Sept. 16	Before treatment	56.5	54.8	111.3
Sept. 19	DDT[1]	0.2	2.0	2.2
	Volck[1]	0.3	3.9	4.2
Sept. 23	DDT	0.3	5.2	5.5
	Volck	0.4	4.8	5.2
	Nicotine Sulfate[2]	86.4	uncounted	—
Oct. 1	DDT	2.7	0.0	2.7
	Volck	2.2	0.0	2.2
	Nicotine Sulfate[3]	106.1	uncounted	—

[1] Applied Sept. 16.
[2] Nicotine Sulfate+Soap. Applied Sept. 17. Young crawling scales killed, but little if any mortality of older stages.
[3] Applied Sept. 24.

benches, and the plants were in much more vigorous condition.

The application of both DDT emulsion and *Volck* killed all crawling young scales and most of the older stage specimens up to half grown scales. Both of these materials apparently had very decided residual effect upon young scales for a long period after application. Examination of old, mature scales in these areas showed many eggs still remaining under the parent scales and numerous small newly hatched young, so that crawling young were appearing steadily during the period of the test.

There was no evidence of foliage injury or any apparent retardation of growth following application, and no discoloration of leaves by spray deposit. As far as the grower was concerned this outbreak which in early September had threatened serious loss in amount and quality of bloom, had been brought to a standstill. However, observations were continued by the writers to determine the period of protection furnished by the sprays and to ascertain whether and when additional applications would be necessary under the conditions prevailing in these houses during the cutting season.—1-9-47.

DDT Wettable Powders and Emulsions Used on American and Asiatic Elms

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Sample lots of wettable DDT powders from five commercial producers were tested on American and Asiatic elm trees in Columbus, Ohio, to determine the persistence of the deposit of these spray materials as compared with that of emulsions containing the same amounts of DDT. Observations on foliage injury also were made.

Foliage injury from the emulsions was apparent within 24 hours and was proportional to the amount of solvent used. In most cases this injury was considered tolerable in that little or no leaf drop followed. Foliage injury resulting from the wettable DDT powders was not apparent until after a 3-week period of exposure. After 4 weeks the injury became very apparent. Although this injury in many cases was no greater than that resulting from the emulsions, the leaf drop that followed was considered to be excessive.

A small power sprayer regulated to maintain a pump pressure of 100 to 120 pounds per square inch was used to apply the wettable DDT sprays. On June 4, 1946, 10 small American elm trees were sprayed with each sample wetting thoroughly both the upper and lower leaf surfaces. Wettable powders containing 50 per cent of DDT were used at a rate equivalent to 16 pounds of DDT per 100 gallons of water.

Three of the products caused light foliage injury and leaf drop and two caused heavy injury and leaf drop when the trees were examined 38 days after treatment.

With the amount of DDT constant and the amount of injury varying among the treatments, it appears that the wetting agents or diluents used may have been responsible for the foliage injury. Heavy rains washed off most of the deposit on the upper leaf surfaces, but most of that on the under surfaces remained for many weeks. Injury first appeared as chlorotic spots on the upper side of the leaves; these spots coincided with visible deposits on the under surface. Injury, including spread of chlorotic spots and leaf drop, became progressively more severe after it once started. Leaf drop on the American elms appeared to be correlated with the extent of chlorotic injury to the leaves. There was also some variation in the amount of injury from tree to tree within each treatment.

On July 17, 1946, to test further the effect of DDT wettable powders, one American and one Asiatic elm tree were sprayed with powders containing 50 per cent and 25 per cent of DDT at each of the following dosages: 4, 8, or 16 pounds of DDT per 100 gallons of water. Another tree was treated with a spray containing 4 pounds of DDT in a 25-per cent wettable powder plus 4 pounds of lead arsenate and 1 ounce of sticker per 100 gallons. Observations were made at approximately weekly intervals to determine when injury first became apparent.

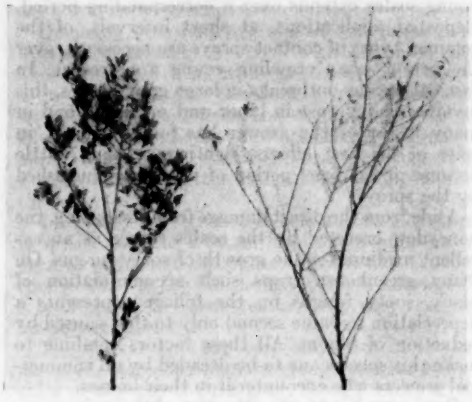

Fig. 1.—Two branches from an Asiatic elm tree. Left, unsprayed branch, right, branch from tree sprayed with DDT (25-per cent wettable powder at 4 pounds of DDT per 100 gallons).

There was no noticeable injury to the Asiatic elms 15 days after treatment, but after 23 days leaf drop was evident. The 50-per cent wettable powder caused 95 to 98 per cent leaf drop at all dosages, and the 25-per cent powder caused 95 per cent leaf drop at the 16-pound dosage, 10 per cent at 8 pounds, 80 per cent at 4 pounds, and 70 per cent when lead arsenate was added to the spray. This defoliation was preceded by a general yellowing of the leaves, but chlorotic spots did not occur as they did on the American elms sprayed earlier in the season. Trees 1, 2, 3, and 6 were twin-stemmed trees, wherein one portion was sprayed and the other portion left untreated. Figure 1 shows branches from the treated and untreated portions of tree 6. Trees 3, 6, and 7 were sprayed at the 4-pound rate usually used for leaf feeders.

The American elms used in this test had dark green, rather leathery foliage, which was not characteristic of trees used in previous tests. After 50 days only slight injury occurred on the foliage sprayed at the 8- and 16-pound rates, while no injury was noted in those sprayed at the 4-pound rate. The comparatively light injury found on the American elm in this series of spray tests may be due to the type of tree selected or to the difference in the time of year that the sprays were applied.—1-16-47.

Effects of DDT on Some Tidewater Aquatic Animals[1]

R. E. TILLER,[2] *Chesapeake Biological Laboratory* and ERNEST N. CORY, *University of Maryland*

The possible effects of DDT on aquatic life when used for mosquito control stimulated an investigation divided into three phases, each phase covering a special set of conditions which might be encountered if large-scale spraying of tidewater areas were to be undertaken. The experimental areas selected were (1) a small freshwater pond adjacent to tidewater, (2) an area subject to strong tidal current and (3) a tidal area with very slight current. All were subjected to similar treatment in an effort to determine the effect of DDT applied to the surface of the water as an oil spray and as a water-dispersible emulsion.

1. SMALL FRESH-WATER POND.—A pond approximately 2 acres in area located at the confluence of the Patuxent River and the Chesapeake Bay, about 100 feet inshore and a half mile inside Drum Point, was selected for this phase of the study. The maximum depth of the pond is 4 feet, and the bottom is uniformly soft and mucky, characterized by a considerable amount of organic material; the only species of animals other than insects observed in the pond were top minnows, *Gambusia sp.*, and frogs, both of which were abundant.

[1] This is a report of one subtitle of Project H51, Department of Entomology, Maryland Agricultural Experiment Station and is article #148, Scientific Contribution #2041.

[2] The assistance of the following members of the staff of the Chesapeake Biological Laboratory, Solomons, Maryland is gratefully recorded: L. E. Cronin, G. F. Beaven, and C. M. Coker.

Table 1.—Details of treatment of pond with DDT.

DATE JULY	TIME	SPRAY USED	GENERAL CONDITIONS	OBSERVATIONS AND REMARKS
18	0900	DDT in oil at concentration of 3 lbs. per acre. Two gallons applied with sprayer.	Light SW wind. Oxygen-saturated at surface.	Spray applied over entire surface.
	1600	———	———	No mortality, all top minnows and frogs appeared normal. No mortality.
19	1430	———	———	No mortality.
24	1500	———	———	No mortality.
24	1545	DDT in water dispersible emulsion. Same conc., amount.	Light SE wind. Oxygen-saturated at surface.	Applied over entire surface.
25	1500	———	———	No mortality.

Table 2.—Details of treatment—tidal area (Strong currents).

DATE JULY	TIME	SPRAY USED	GENERAL CONDITIONS	OBSERVATIONS AND REMARKS
18	1100	DDT in oil, concentration 3 lbs. per acre by pressure sprayer.	Tide—slack Wind—Light SW Bottom—Sand Temp. H_2O—26.2° C. Salinity—8.2 o/o O_2—5.30 cc/l	Specimens placed in net at 1000 Spray applied along windward side of net, to a point 15 ft. beyond sides of net. Oil film remained until carried off by tide.
	1630	———	———	No mortality.
	1700	DDT in water-dispersible emulsion, at same concentration.	Tide—slack, no other observations.	
	1900	———	———	No mortality.
19	1130	———	———	1 dead trout, caught in net by mouth parts.
21	0700	———	———	4 dead trout, 4 dead croakers, all enmeshed in net. Remaining fish apparently normal. Four fish missing (see below)

Table 3.—Treatment of tidal area with slight current.

DATE OCTOBER	TIME	SPRAY USED	SPECIMENS	GENERAL CONDITIONS	OBSERVATIONS AND REMARKS
17	1415	4 pts. 5% DDT in oil	27 adult female crabs 3 male crabs 19 rock (av. weight 1 lb.)	Tide—slack Bottom—muddy Remaining observations made at end of expt.	Specimens placed in net at 1230
	2000	———	———	Temp. H_2O—17.6° C. pH—7.6 Salinity—15.4% O_2—5.30 cc/l. Samples taken at 3½' below surface.	1 adult female crab dead. All fish appeared normal. All specimens removed to live car, taken from experimental area. All crabs normal. Seven rock dead.
18	0930	———	———		
19	1200	———	———	———	3 adult female crabs dead. All fish appeared normal.
23	1000	———	———	———	All fish appeared normal. 3 adult female crabs dead. Experiment concluded.
17	2020	4 pts. 30% DDT in water emulsion-dispersible.	27 adult female crabs 5 male crabs 20 rock (av. weight 1 lb.)	Tide—slack	Specimens placed in net just prior to spraying.
18	0930	———	———	———	Eight crabs dead (see note below). All fish appeared normal. Specimens placed in live car, taken from experimental area.
19	1200	———	———	———	20 adult female crabs dead. All
23	1000	———	———	———	fish normal. Three adult female crabs dead. Fish appear normal. Experiment concluded.

2. TIDAL AREA—STRONG CURRENTS.—A 15 by 15 foot net enclosure was constructed in 7 feet of water near the northern shore of the Patuxent River approximately a half mile inside Drum Point. The net resembled the 'head' of a small pound net, and was geared to be raised and lowered by lines attached to the corner poles. Live fish were obtained from a commercial pound net 8 miles north of Drum Point, and were transported in a live-car towed slowly by a power boat. The species and numbers used were as follows, average weight, 8 to 12 ounces each: 10 trout, *Cynoscion regalis*, 10 croakers, *Micropogon undulatus*, 8 rock, *Roccus saxatalis*, 5 menhaden, *Brevoortia tyrannus*, 1 spot, *Leistomus xanthurus* and 1 bluefish, *Pomatomous saltatrix*.

At the time of the observations made on July 21, two rock, one menhaden and the bluefish were missing. These fish may have leaped over the net at high tide, or may have been captured by fish hawks, four of which were observed in the area. It is known that these birds 'fish' pound nets, and are so numerous in some areas that netting is placed over the pound to protect the catch.

3. TIDAL AREA—VERY SLIGHT CURRENT.—The net enclosure used in the preceding phase of the investigation was transferred to a sheltered cove at the upper end of Mill Creek, a small tidal estuary of the Patuxent River in which conditions, except for tidal current, closely paralleled those of the Drum Point area.

The mortality observed in the preceding experiment, caused by trout and croakers becoming enmeshed in the net, suggested that rock would be more satisfactory test fish. Forty rock were obtained from the same pound net, and hauled in the live car to the Mill Creek area. This stage of the study was extended to include the effects of DDT on crabs. Six dozen blue crabs, *Callinectes sapidus* Rathbun, were obtained from a commercial crab pot fisherman operating in the nearby Chesapeake Bay. These were sorted to eliminate badly injured or 'poor' (recently shed) crabs, and were 'gloved' with rubber tubing to prevent their biting each other.

Close observation of the dead crabs showed varying degrees of pre-experimental injury, ranging from slight bites to the loss of one or more legs. Several of

Table 4.—Second Mill Creek experiment.

DATE NOVEMBER	TIME	SPRAY USED	SPECIMENS	GENERAL CONDITIONS	OBSERVATIONS AND REMARKS
7	1230	4 pts. 5% DDT in oil	7 male, 3 adult female crabs 20 rock 25 oysters	Tide—slack Temp. H_2O—15.7° C. Salinity—16.0% pH—7.5 O_2—4.30 cc/l.	Specimens placed in net just prior to spraying.
	1835	———	———	———	All specimens appeared alive and normal. Specimens taken from experimental area.
8	1000	———	———	———	All specimens alive.
10	1130	———	———	———	All specimens alive.
13	1400	———	———	———	All specimens alive. Experiment concluded.
7	1835	4 pts. 30% DDT in water. Dispersible emulsion.	23 male, 3 adult female crabs 20 rock.	Tide—slack Temp. H_2O—15.5° C. Salinity—15.5% pH—7.5 O_2—4.80 cc/l.	Specimens in net just prior to spraying.
8	1000	———	———	———	All specimens alive, placed in live car, taken from experimental area.
10	—	———	———	———	All specimens alive.
13	—	———	———	———	All specimens alive. Experiment concluded.

Table 5.—Mill Creek experiment. Oysters only.

DATE NOVEMBER	TIME	SPRAY USED	SPECIMENS	GENERAL CONDITIONS	OBSERVATIONS AND REMARKS
20	1205	4 pts. 30% DDT in water dispersible emulsion.	25 oysters	Tide—slack Temp. H_2O—11.8° C. Salinity—15.2‰ O_2—5.65 cc/l.	Specimens placed in net on previous evening. Spraying done with minimal disturbance of the water.
	1400	———	———	———	All specimens alive. Live nereid worms, and mussels on oyster shells.
25		———	———	———	All specimens alive, evidence of growth. Experiment concluded

the lives crabs had lost one or both 'gloves,' which were replaced before transferring the crabs to the live car.

The mortality that occurred in the Mill Creek study indicated that additional observations were needed, since there was evidence that pre-experimental injury might have been a factor in the death of the crabs. This need was further emphasized by the fact that only seven rock were killed in the experiment, while the remaining fish appeared normal after seven days. The experiment was therefore repeated, with an attempt to reduce or eliminate causes of injury or death in handling the specimens. The crabs were taken individually from a trot-line, and immediately 'gloved'; the fish were taken from the same net, but were handled more carefully, and towed more slowly in the live car.

In addition to the fish and crabs, a wire bag containing 25 oysters, *Ostrea virginica*, was suspended just above bottom in the net enclosure. Sufficient time was allowed for the oysters to commence feeding, and the DDT was applied with as little disturbance of the water as possible.

Oysters were not included in the second phase of this experiment, but the possibility of injury to bottom dwelling animals seemed greater with the water-dispersible emulsion of DDT than with the oil solution, and a separate experiment was conducted under the same conditions, using only oysters.

The data presented in this report do not justify definite conclusions regarding all the effects of DDT as it might be used in large scale spraying operations. However, an effort has been made to conduct the tests under as nearly typical conditions as possible, using concentrations of DDT greatly in excess of those which would be employed in any anticipated spraying programs.

Effects of Ultra-Violet Radiation on *Tenebrio molitor*

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The following experiment was carried out to determine whether ultra-violet radiation in wave lengths shorter than 3000 Ångstrom units with exposures up to 30 minutes would be lethal to the insects. Little having been done with lethal effects of ultra-violet rays on adult or immature insects, it was necessary to refer to the various publications dealing with ultra-violet radiation upon bacteria and plants.

PREVIOUS WORK WITH PLANTS.—Many and varied experiments have been performed upon bacteria (Dugger 1936) since it has been discovered that sunlight, in the short ultra-violet range of the spectrum possessed lethal qualities. Later experiments proved that only those waves shorter than 3100 Å had bactericidal value; especially those from 2000-2950 Å. These have lethal qualities 10 to 12 times greater than the longer ones. The experiments performed with plants (Dugger 1936; Johnston 1936; Popp & Charlton 1938) have been even more numerous and intensive; the results obtained tend to confirm the belief that the middle and short ultra-violet rays definitely retard growth or check it completely. The apparent effects are stunting, curling of the leaves, and necrosis of the tissues; the actual injury is the destruction of the epidermal cells.

PREVIOUS WORK WITH INSECTS.—Definite effects on the reproductive functions of insects irradiated by ultra-violet are known to occur. *Drosophila melanogaster* has been the insect commonly used. Mutations (Shultz 1933) are usually observed after irradiation of the insects; translocation of the sperms (Demerec *et al.* 1942) has occasionally been observed. Working with eggs of the bean weevil, Macleod (1933) found that rays less than 3126 Å were definitely injurious, causing lethal effects which varied inversely with the age of the eggs, but that longer rays may have been beneficial, for the emerging treated larvae weighed more than the controls. Eggs of grasshoppers (Ray & Bodine 1938) subjected to the rays show a decrease of hatch, accompanied by an increase in respiration. Extreme variations in sensitivity were observed. Ultra-violet seems to act mainly on the embryo rather than the yolk or egg components. The chorion and cuticle were resistant to primary radiation, but absorbed secondary ones. Bees (Bertholf 1933) irradiated with ultra-violet to determine if beneficial effects could be induced were harmed by long exposures to the rays, though short doses gave slight indications of beneficial effects, but were impractical for commercial purposes. Irradiations with waves shorter than 2970 Å were decidedly harmful. The lack of information concerning the lethal effect of ultra-violet on insects warranted the notes summarized in this paper.

APPARATUS.—A mercury vapor arc lamp in quartz on a direct current of 130 to 140 volts and 3 amperes, pre-heated for 15 minutes. The insect used was *Tenebrio molitor*. The distances between the specimens and lamp were 8 and 18 inches.

METHOD.—A given number of specimens were placed in a petri dish, covered with a filter and exposed to the rays. For irradiation purposes the lamp was placed directly above the insects. After the required exposure the specimens were allowed to remain uncovered for 24 hours, when the percentage mortality was determined. Both adults and larvae were used.

RESULTS.—The effects of radiation on *Tenebrio molitor* tend to show that ultra-violet does not penetrate the cuticula deeply. The final tempera-

Table 1.—Filter data and results.

FILTER	SPECTRAL RANGE (ÅNGSTROMS)	TOTAL ENERGY TRANSMITTED INTENSITY		DISTANCE AND EXPOSURE		TOTAL NUMBER INSECTS		PER CENT MORTALITY	
		Per cent	(watts/cm²)	D.	E.	A.	L.	A.	L.
G586A	3000–4360	25	$5.41–10^{-5}$	18	30	10	40	0	0
Noviol O	3890–7200	50	$10.82–10^{-5}$	18	30	27	62	25	8
Corex D	2500–7200	75	$16.22–10^{-5}$	18	30	28	52	46	3.6
Corning 791	2100–28000	87	$18.92–10^{-5}$	18	30	1	45	0	9
Corning 5970	3100–4200	85	$18.40–10^{-5}$	18	30	—	10	—	0
Unscreened arc	2350–6230	100	$21.65–10^{-5}$	18	30	—	86	—	2
G586A				8	3	—	40	—	100
Noviol O				8	3	—	40	—	90
Corex D				8	3	—	40	—	100
Corning 791				8	3	—	40	—	100
Unscreened Arc				8	3	—	40	—	100

D.—distance in inches.
E.—exposure in minutes.
A.—adults.
L.—larvae.

tures arrived at by exposures of 3 and 15 minutes for distances of 8 and 18 inches were 74° and 40.5° C. respectively, indicating that considerable infra-red was involved. Both temperatures are lethal to *Tenebrio molitor*. The adults were more susceptible than the larvae to the treatment; probably their darker coloration and rougher surfaces absorbed more infra-red. The rate of activity increased up to a certain undetermined temperature, when the insects turned on their backs, and eventually became still. Exceptions were those irradiated through either filters *G586A* or *Corning 5970*.

CONCLUSION.—Since no attempt was made to keep the treated specimens under long-time observation, or to study the rays' possible effects upon the insects' reproductive capacities, it may be concluded that (1) ultra-violet radiation has no apparent effects upon either adults or larvae of *Tenebrio molitor* (2) the rate of activity of the insect decreases after prolonged exposure to the rays (3) only where heat in the form of infra-red was concerned were there any positive effects.—1-27-47.

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Comparison of Insecticides for Cotton Insect Control and the Effect of Copper on Yields[1]

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Results of experiments conducted at College Station during 1942 (Gaines 1944) indicated that basic copper arsenate was effective against the bollworm and that this material increased the yield of cotton over lead arsenate. This increased yield was thought to be partially due to the presence of copper. The results of investigations reported by Cook (1923) indicated that copper sprays increased the yield of potatoes in various parts of the country. In field experiments (Churchman *et al.*, 1936) conducted in North Carolina, South Carolina and Virginia, the average yield of cotton was increased 17.9 per cent by adding copper sulphate to the fertilizer. Other references in literature indicate that copper and zinc may exert a stimulating action on various crops in certain types of soil.

Tests were conducted in the Brazos river bottoms during 1942 and 1946 for the purpose of studying the effect upon yield of copper and zinc applied with an insecticide to the leaves, and of copper applied independently to the soil. The effectiveness of the materials for bollworm, *Heliothis armigera* (Hbn.) and weevil, *Anthonomis grandis* Boh., control were compared.

[1] Technical contribution No. 999 Texas Agricultural Experiment Station in cooperation with the Bureau of Entomology and Plant Quarantine, United States Department of Agriculture.
[2] H. A. Dean assisted in taking the field notes.

Table 1.—The average insect infestation and yields of seed cotton following treatments as indicated at College Station, Texas.

Treatments	1942				1946				
	Boll worm Boll Injury[2]	Aphids Per Sq. Inch[3]	Yield Seed Cotton Per Acre	Gain in Yield Over Check	*Weevil* Punctured Squares[1]	*Boll worm* Boll Injury[2]	Aphids Per Sq. Inch	Yield Seed Cotton Per Acre	Gain in Yield Over Check
Lead Arsenate	10.5	27.3	691	66	29.9	6.1	30.6	1584	102%
Lead Arsenate plus Copper	11.5	18.0	821	97	29.6	5.1	30.8	1800	130
Lead Arsenate (Copper applied to soil)					27.7	5.1	15.4	1670	113
Basic Copper Arsenate	5.5	13.8	996	139					
Lead Arsenate plus Zinc	9.3	9.5	827	99					
Calcium Arsenate	13.1	21.2	575	38	28.0	9.5	26.5	1670	113
Benzene Hexachloride					27.6	21.5	1.6	1368	74
Check	22.7	7.7	416		52.0	11.7	12.1	783	

[1] Average of 8 records taken from June 21 to July 27.
[2] Average of 7 records taken from July 28 to Aug. 24; average of 5 records taken from July 22 to Aug. 14.
[3] Average of 1 record taken after last application of insecticides.

FIELD PLATS AND TREATMENTS.—In 1942, the plats were arranged in randomized blocks and each treatment was replicated 3 times. The dusting area of each plat was 0.1 acre (13 rows wide) and the picking area after the buffers were eliminated was 0.05 acre. The following insecticides were used: calcium arsenate-*Pyrax* (50-50), lead arsenate-*Pyrax* (50-50), lead arsenate-*Pyrax-copper* "34" (50-40-10) the mixture containing 3.4 per cent metallic copper, lead arsenate-*Pyrax*-zinc sulphate (50-40-10)—and basic copper arsenate. All the insecticides were applied at an average rate of 15 to 16 pounds per acre except calcium arsenate-*Pyrax* which was applied at about 12 pounds per acre. Eight applications of all insecticides were made at 5-day intervals from June 19 to August 20, but three applications were washed off by rains.

In 1946, the plats were also arranged in randomized blocks and each treatment was replicated 3 times. The dusting area of each plat was 0.05 acre (11 rows wide) and the picking area after the buffers were eliminated was 0.022 acre. The following materials were used: calcium arsenate, benzene hexachloride-inert mixture containing 5.75 per cent gamma isomer, lead arsenate, lead arsenate-copper oxychloride mixture containing 5 per cent metallic copper, and lead arsenate mixture applied as a dust. The foregoing blocks included plats receiving 3.3 pounds of copper sulphate per acre applied to the soil as a side dressing when the cotton plants were in the seedling stage and lead arsenate dust during the growing season. Nine applications of all insecticides were made at approximately 5-day intervals from June 17 to August 6. Three of the applications were made at an average rate of 6 pounds per acre before the bollworm moths transferred to cotton; the later applications were applied at an average rate of 10.4 pounds per acre after the bollworm began to cause injury.

RECORDS.—The insect infestation records were made at approximately 5-day intervals in the usual manner. One hundred squares were examined on consecutive plants in each plat and the percentage punctured by weevils was recorded. One hundred bolls were examined on consecutive plants in each plat for the bollworm injury record. Aphid counts were made by recording the aphids present on a square inch of leaf surface in the center of the fourth leaf from the top, on 100 consecutive plants in each plat.

RESULTS.—In 1942, the average bollweevil infestation was less than 5 per cent on the check plats throughout the season, and did not affect the yields. The bollworm occurred in injurious numbers and caused considerable injury on the untreated plats. Basic copper arsenate gave better control of the bollworm than either lead arsenate or calcium arsenate. Lead arsenate gave better control than calcium arsenate. The addition of copper and zinc to lead arsenate increased the yield 18.8 and 19.7 per cent, respectively, over lead arsenate alone. The numbers of leaves shed during a period in early August were recorded, but there was little difference in these numbers in the plats receiving the different treatments. If the copper or zinc acted as a fungicide, this record failed to show it. The basic copper arsenate gave a higher yield than any other treatment used, but it was concluded that some of this increase might be due to the stimulating effect of copper upon the plant, as well, perhaps, as its effectiveness in controlling plant diseases.

Since copper and zinc appeared to contribute to increased yield during 1942, the work was continued in 1946 using copper in the test conducted in the Brazos river bottoms, but not in the same field. During this season, the weevil caused more injury than the bollworm. The lead arsenate, the benzene hexachloride-inert mixture containing 5.75 per cent gamma isomer and the calcium arsenate gave about equal control of the weevil. Lead arsenate gave better control of the bollworm than did calcium arsenate. The benzene hexachloride mixture prevented aphid increases but permitted increased bollworm injury. The copper applied as a dust with lead arsenate gave a 14 per cent increase in yield over lead arsenate alone, but only increased the yield 5 per cent when applied to the soil directly.

SUMMARY.—Basic copper arsenate used 1 year was effective against the bollworm and gave the highest increase in yields. Copper as a dust increased yields an average of 16 per cent in the experiments conducted during 1942 and 1946. These increased yields resulting from the use of copper are regarded as being due, at least in part, to the stimulating action of the copper upon the plant, but the possible benefit of copper as a fungicide cannot be overlooked. Lead arsenate proved to be almost as effective as calcium arsenate when used against heavy infestations of weevils and was more effective against the bollworm. The benzene hexachloride-inert mixture containing 5.75 per cent gamma isomer was effective against the weevil and prevented aphid increases, but permitted increased bollworm injury.—1-23-47.

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Parasites of a Bag-making Pierid, *Eucheira socialis*[1] in Morelos, Mexico

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The butterfly, *Eucheira socialis* West., called "mariposa del madroño," a pierid indigenous to Mexico, has been known for centuries, and its silken bags are said to have been used for paper by the Indians before the Spanish conquest (Hoffmann 1910). Apparently none of its parasites have been recorded.[2]

[1] Determination checked by C. Heinrich, of the Division of Insect Identification, Bureau of Entomology and Plant Quarantine. All parasites were determined by specialists of that Division.

[2] Checked by personnel of the United States Department of Agriculture Library, who examined Parts 5 and 6 (Lepidoptera, A–F) of A Catalogue of the Parasites and Predators of Insect Pests, by W. R. Thompson.

In traveling the highway from Mexico City to Cuernavaca the writer occasionally observed this insect feeding on *Arbutus* sp., which grows on the southern slope of the mountains 34 to 40 miles from Mexico City at an altitude of 7000 to 8500 feet. When these white bags were first noticed in 1943 they were not abundant, but in the spring of 1944 they were more numerous, and the trees were completely defoliated by the larvae. It was not uncommon to see from 100 to 250 bags on trees 30 to 50 feet in height.

In the spring of 1944 several bags were brought to the laboratory for observation. Adults reared from dipterous larvae and puparia that dropped to the bottoms of containers holding the bags were identified by M. T. James, as two species of Larvaevoridae. One species, *Zenillia virilis* A. and W., parasitized approximately 2 per cent of the host population. Another species, which parasitized about 10 per cent of the larvae, represented a new genus and species, which James (1945) named *Eucheirophaga lugubris*. Both these flies are primary parasites, a fact determined by observed parasitization of the larvae. Puparia were found within the host chrysalids on only a few occasions.

In the spring of 1945 the reduction in the number of bags of *Eucheira socialis* and the decrease in defoliation of *Arbutus* trees over that in 1944 were very marked, with the percentage of parasitization much higher (Table 1). *Eucheirophaga lugubris*, the predominating parasite in 1944, was not recovered, while *Zenillia virilis* was more common than in 1944. Another larvaevorid, not reared in 1944, as com-

Table 1.—Parasitization of *Eucheira socialis* in bags collected in Morelos, Mexico, 1945.

Eucheira socialis per Bag			Parasitization[1]			
			Larvae	Chrysalids		
Total Larvae and Chrysalids	Dead Larvae and Chrysalids[2]	Emerged Adults	*Winthemia* sp. or *Zenillia virilis*	*Winthemia* sp. or *Zenillia virilis*	*Brachymeria* sp.	Larvae and Chrysalids Combined
Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Per Cent*
			Collection on March 28			
58	24	6	0	9	19	48
35	10	17	0	1	7	23
178	59	50	7	10	52	39
115	59	45	6	3	2	10
20	14	0	1	3	2	30
Total 406	166	118	14	26	82	
Per cent—	41	29	3	7	20	30
			Collection on April 16			
114	46	0	14	6	48	60
48	23	1	4	4	16	50
41	18	0	4	1	18	56
75	38	0	18	10	9	49
56	25	0	3	1	27	55
35	14	0	9	3	9	60
30	11	0	6	1	12	63
50	15	0	9	2	24	70
85	27	2	21	2	33	66
Total 534	217	3	88	30	196	
Per cent—	40	1	16	6	37	59

[1] Fifteen specimens of *Monodontomerus viridiscapus* and 4 of *Apanteles* n. sp. are not included here.

[2] It was not determined why the larvae and chrysalids died. Of the dead material, 73 per cent were chrysalids and 27 per cent larvae.

mon as *Z. virilis* in 1945, was determined by C. T. Greene as *Winthemia* n. sp. This species, determined by C. W. Sabroskv, was also reared from cutworms (Phalaenidae) on potato foliage on August 10, 1945, at El Guarda, Distrito Federal, at an altitude of 9800 feet. Puparia of one of these larvaevorids (species not determined) were held at 25° C., and they completed their development in 14 days. Chrysalids of the butterfly required 24 and 25 days to complete development at this temperature.

Three hymenopterous parasites were also found in 1945. The most common one was *Brachymeria* sp. (probably n. sp.), determined by A. B. Gahan. It appears to be a primary parasite. The writer examined 278 chrysalids (Table 1) having round emergence holes, and in almost every case the cast skin of this wasp was found within.

Fifteen specimens of *Monodontomerus viridiscapus* Gahan were obtained. Gahan (1941) described this species from Orizaba, Mexico, without any other data. In recent correspondence he expressed the belief that this is a secondary parasite, possibly of some dipteron. He also stated that some species of this genus are apparently primary parasites of Lepidoptera and that some are both primary and secondary. This is probably a secondary parasite of the Larvaevoridae, which attacks *Eucheira socialis* because the puparia are apparently large enough to support it.

Cocoons attached to the inner web of a bag of this butterfly produced four adults of *Apanteles*, which C. F. W. Muesebeck determined as a new species. From the general habits of the group, the writer assumed that this is a primary parasite. As the cocoons were attached to the lining of the bag, this parasite is believed to attack *Eucheira socialis*.

A summary of the contents of the bags of *Eucheira socialis* held for observation in 1945 is given in Table 1. It is readily seen that *Brachymeria* sp. parasitized many more chrysalids than did either of the dipterons, *Winthemia* sp. or *Zenillia virilis*. Larvae in the bags collected on March 28 apparently were not large enough to become heavily parasitized since 29 per cent of the chrysalids developed into butterflies and 30 per cent of them produced adult parasites. For the bags collected on April 16 the results were quite different, because only 1 per cent of the chrysalids developed into butterflies and 59 per cent of them produced adult parasites. The percentage of chrysalids that did not produce either butterflies or parasites was practically the same for the bags collected on both dates, i.e., 41 and 40 per cent, respectively. Mortality in the bags, from parasites or undetermined causes, reached 100 per cent in several instances. Apparently high parasitization of this social butterfly was very common in the field in 1945, as few bags could be found in 1946.

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Corn as a Trap Crop for the Cotton Bollworm[1]

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The use of corn as a trap crop to protect cotton from injury by the bollworm has been widely recommended not only in the United States, but wherever cotton is grown. In fact, corn is frequently recommended as a trap crop to protect many other crops, besides cotton, from bollworm injury. Corn is presumably useful for this purpose because as is well known fresh corn silks are particularly attractive to ovipositing bollworm moths. Furthermore corn is the favored host of the bollworm (Isely 1935).

The recommendation of corn as a trap crop is supported by little direct experimental evidence, although there are doubtless many widely scattered unreported observations which justify it. The bollworm moth is an active flier capable of migration for many miles (Blanchard 1942) and, for this reason is not a ready subject for plot experiments.

During the summer of 1946, there was opportunity to make notes on the effectiveness of plantings of corn in attracting ovipositing moths from cotton in a number of counties in Arkansas. These notes together with others made during previous bollworm outbreaks are presented at this time.

Severe injury to cotton by the bollworm is erratic in occurrence. Probably, the insect destroys some bolls in every field in Arkansas every year. Within the past 25 years there have been seven outbreaks on cotton, extensive enough to involve five or more counties. Within cotton fields themselves local differences in infestations may occur. Bollworm moths tend to deposit most eggs on rapidly growing plants, as has been noted by Thomas & Dunnam (1931), and infestations may be concentrated in the parts of fields which have been heavily fertilized. Scattered stalks of corn or single rows of corn in a cotton field also attract moths which deposit eggs not only on the corn but on the cotton plants nearby. This results in a heavy concentration of infestation.

Observations made during the outbreak of bollworm in cotton in 1925 indicated that the infestation had begun when practically no corn in silk was available as a trap crop in the counties where the outbreak occurred. The injury during this season was unusually severe. In no field in four counties where observations were made, was the percentage of injured bolls less than 25 per cent, and frequently the injury exceeded 90 per cent.

The outbreak of 1925 covered the greater part of nine counties in the west central part of Arkansas. These are hill counties and did not produce large acreages of cotton. The corn acreage was also relatively small although it was more than double that of cotton. Practically all the corn was early and the silking period had passed by the third week of July. The summer was relatively dry in that part of the state, and drought had cut the silking period short. Most of the worms which caused the severe boll damage hatched in August, indicating that the eggs had been deposited after the period of silking of corn had passed. This outbreak, unlike some of the more recent ones, was not complicated by dusting

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for boll weevil control nor by aphid infestations. The bollworm infestations developed when no trap crop was available. This is not conclusive proof, however, that a trap crop would have been effective had it been present.

Evidence regarding corn as a trap crop during the bollworm outbreaks in southwestern Arkansas in 1929 and in the Arkansas River Valley in 1936 were similar to those in 1925. During both years, the outbreak began on cotton when no silking corn was available in the areas where severe injury occurred. During both summers, drought appeared to be a factor in shortening the period of silking of late corn in the localities where the outbreaks occurred. Aphid infestations and dusting for weevil control were not factors during these years.

In 1941, there was widely scattered injury to cotton by the bollworm in 25 counties. This injury was not concentrated in any part of the state and did not appear to be related to any local condition. In many instances there did appear to be a relationship between bollworm damage and previous infestations of the cotton aphid. It was not possible to check carefully the conditions.

A scattered bollworm outbreak in cotton occurred during the summer of 1946. In 11 counties it was estimated that 25 per cent or more of the bolls were destroyed in at least 10 per cent of the cotton acreage of the counties. The outbreak was not as intense and did not cover whole areas as did some of those of the previous years. Instead, the injury tended to be scattered and local.

Special attention was given to fields in five counties where these outbreaks occurred, to determine, if possible, the conditions favoring bollworm injury and the value of silking corn as a trap crop. Records were made in 21 fields where 25 per cent or more of the bolls were destroyed. In all of these fields aphids had been present, and the aphid infestation had followed dusting for control of the boll weevil or leafworm. No serious bollworm damage was noted in these counties in fields in which aphid infestations were not obvious. A few fields with aphid infestation escaped bollworm injury. Ovipositing moths of the bollworm may have been concentrated on the cotton which was sticky with honeydew, or the predators may have been too fully occupied with destruction of aphids to be effective in destroying bollworm eggs. In any case, there was an obvious relationship between the aphid infestation and bollworm injury. Thus the outbreak appeared to be artificial in that it was developed by previous activity in insect control.

There was no freshly silking corn near any of these 21 fields at the time the infestation was initiated. However, there were plantings of late corn near 19 of them which began silking after hatching of worms began. In four of these 19 fields moths continued to deposit eggs in sufficient numbers to maintain a destructive infestation of worms. In the other 15, the ovipositing moths apparently transferred their attention from cotton to corn and little late infestation of cotton followed. In one instance where a small planting of late corn, less than 2 acres, was adjacent to a field of cotton of about 60 acres, the average number of eggs on fresh silks was over 200 to the ear. Many eggs were also scattered over these corn plants. In all of these 15 fields, corn was effective as a trap crop and the infestation of cotton declined sharply with the beginning of silking.

SUMMARY.—Corn in silk appeared to be effective in most cases in attracting moths of the cotton bollworm from cotton during a bollworm outbreak on cotton in Arkansas during the late summer of 1946. In exceptional instances, however, where cotton was heavily infested with aphids, severe bollworm injury continued notwithstanding the proximity of silking corn. In this and previous outbreaks in all instances of severe injury no freshly silking corn was near the injured fields at the time the infestation of cotton began. Bollworm outbreaks appear to be favored not only by the occurrence of aphids, but also by dry, hot weather, which shortens silking during midsummer.

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Relation of Crib Type to Weevil Injury to Corn[1,2]

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The rice weevil, *Sitophilus oryza* (L.), is the most destructive pest of corn in farm storage in Arkansas. Its importance in the South, and particularly in Alabama, was pointed out by Hinds (1914) who estimated that the damage which it caused to corn in storage in that state during a single year was not less than four million dollars. In Mississippi, Hamner & Lyle (1943) have estimated the annual damage by weevils to corn in storage as varying from 5 to 8 million dollars. In outlining procedures for protection of grain in farm storage from insect damage, Cotton (1938) divided the United States into four zones depending upon the severity of the problem. The southeastern states, and this included Arkansas, he placed in a zone in which he stated that farm storage of grain, is "extremely hazardous," and is not recommended except for short periods.

Losses caused by the rice weevil in Arkansas are undoubtedly less than those in the Gulf States. Nevertheless the damage at times is nearly complete, at least as far as nutritive value of the grain is concerned. On the other hand corn frequently escapes injury altogether. An inquiry regarding the causes of this variation is desirable since fumigation, the commonly recommended method of control of weevils in stored corn, is not possible in most corn cribs in Arkansas.

Three factors which most regularly control the degree of infestation are continuous storage, the weather, and the type of crib. Principal attention will be given to the relationship of the type of crib to infestation. The other factors will be discussed as they modify the importance of crib type.

This is a summary of accumulated observations[3] on corn in storage over a period of 6 years from 1941

[1] Research paper No. 853 Journal series, University of Arkansas, published with permission of the Director of the Arkansas Agricultural Experiment Station.

[2] Richmond-Program paper.

[3] Some of the records were made by Charles Lincoln, Extension Entomologist.

to 1946 inclusive.[3] All of the data are from cribs in which storage was continuous, that is, from one harvest season until the following season when corn was hardening in nearby fields.

Continuous storage from one crop season to another is an almost essential characteristic of severe injury. This makes continuous breeding possible, since the infestation is carried by the remnant of one crop from one season to the new crop of the next. Corn held until the beginning of summer may also be severely injured. On the other hand, where the crop is utilized before the end of winter the loss is seldom important. Storing or corn from one season to the next has increased during the past few years as a result of an increased corn acreage as a part of cotton replacement, and with an increased interest in livestock production.

The two weather factors which have a repressive effect on weevil population are summer drought and low winter temperature. Weevil infestations in corn, both in storage and in the field, were less frequent and less severe during summers of scant rainfall than during wet seasons. This is a response to the inhibiting effect of low moisture content of grain upon survival and reproduction of weevils. The effect of low moisture content of grain upon weevil population is generally recognized (Cotton & Frankenfeld 1945; Robinson 1946).

The rice weevil is a tropical insect and is relatively much less important as a pest of grain in the North than in the South. It was noted by Hinds & Turner (1911), in Alabama, that when the winter temperature falls below 20° F. there is a high mortality of weevils. Temperatures lower than this occur at times in the greater part of Arkansas during most winters. The importance of favorable winter temperature is also indicated by the fact that the proportion of infested cribs is three times as great in the two tiers of counties along the southern border of the state as in the central and northern counties.

Approximately 43 per cent of the cribs in barns were found to be infested. On the other hand, among cribs which were separate from barns and used only for corn storage, only 13 per cent were apparently infested with weevils. Among the cribs in barns, all of those with floors on the ground were infested. These floors were usually of concrete but sometimes of planks. Cribs with floors on the ground were usually the ones with the largest weevil population. The uninfested cribs in barns all had floors high enough above the ground to permit air circulation under them.

Probably the difference in degree of infestations between different types of cribs is largely because of differences in moisture content of the grain stored in them. Cribs in barns with concrete floors, with hay lofts overhead and in which livestock introduce a certain amount of moisture, respond to the drying effect of drought more slowly than slatted cribs used only for corn storage with good ventilation below and direct exposure to the sun's heat on the roof. The floor on the ground is also obviously an important source of moisture. One pair of cribs on either side of a driveway in a barn have been under observation for 5 years. The floor on one side is concrete and on the other of timber about 18 inches above the ground. The side with the concrete floor has always been infested even during the driest summer. On the other side infestations faded out during three summers included in this period.

Cribs in barns also favor survival of weevils during winter more than slatted cribs used only for corn storage. Warmth from animals and insulation provided by hay reduces the extremes of temperature both in winter and summer. In a number of barns under observation in the northern part of Arkansas weevils survive winter regularly in large numbers while their occurrence in open cribs is erratic.

SUMMARY.—The type of crib in which corn is stored on farms is an important factor in determining the severity of injury by the rice weevil. During dry summers, the weevil infestation is often absent in open isolated cribs while it usually occurs in cribs in barns. This is probably because the moisture content of corn is more rapidly reduced below the point where weevils can survive in isolated cribs than in barns. Also winter temperatures in isolated cribs are more unfavorable to weevils than in barn cribs.

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Resistance of New Sweetpotato Seedlings and Varieties to Attack by the Sweetpotato Weevil

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For a number of years the Louisiana Agricultural Experiment Station and the Bureau of Plant Industry, Soils, and Agricultural Engineering have been engaged upon a program of breeding sweetpotatoes to improve their quality, production, and disease resistance. In 1939 cooperative plans between the Bureau of Entomology and Plant Quarantine and the above agencies were formulated for the examination of various seedlings and varieties for infestation by the sweetpotato weevil, *Cylas formicarius elegantulus* (Summers), in an effort to find some that were weevil-resistant.

During 1939 and 1940 small field plots ranging in size from single rows containing five plants to single rows 1 rod long were grown in St. Landry Parish, La. Most of the seedlings and varieties were grown without replication; only one or two, which were used for standards of comparison, were replicated. There were 304 plots in 1939 and 138 in 1940. While these plots were being harvested and observed for quality,

[1] Acknowledgment is made to Dr. Julian C. Miller, Department of Horticultural Research, La. Agricultural Experiment Station, who assisted in this work by supplying the plants used in the experiments reported in this paper.
Cotton States Branch Program.

production, and disease incidence, examinations were made for weevil infestation. Owing to the rapidity of the harvest, only hasty examinations could be made. During both years, however, more weevils were found in Menes Moeder (U. S. Introduction 47442) than in any of the other varieties.

Owing to the small size of the plots, uneven plot distribution and weevil exposure, and insufficient replication, coupled with the limited time available, in subsequent years a smaller number of seedlings were planted in randomized and perlicated plots, each consisting of a single row from 32.5 to 40 feet long. Seedlings were selected that appeared to have different growth characteristics and to represent types producing potatoes that were higher and lower than average in moisture, starch, and carotene content. Prior to harvest crowns of all the plants were examined for weevil infestation, and at harvest all infested potatoes were culled out and the weights of the infested and uninfested potatoes were recorded. Because of the variation in production between the seedlings, the potato infestation records were converted to percentages.

In 1941 four varieties, consisting of Unit I Porto Rico, Nancy Hall, L4-5 (recently named Pelican Processor), and Menes Moeder, were grown in a latin square. Unit I Porto Rico had the lowest infestation of plants and potatoes, and L4-5 had significantly more infested potatoes than the others. There was no difference between the two other varieties. It appeared that large, soft stems or crowns were favorable to weevil infestation.

In 1942 four seedlings and a variety were grown in a latin square. Seedlings 32-10-5 and 2×16-39-2 had fewer infested crowns than the others, and seedlings 32-10-5, 1×6-39-15 and a variety Unit I Porto Rico had the lowest percentage of infested potatoes. Seedling 2×16-39-2 had the most infested potatoes and the fewest infested crowns, and seedling 1×6-39-15 had next to the fewest infested potatoes and by far the largest number of infested crowns. An additional seedling, 32-106-25, and another variety, Purple Stem Triumph, were planted in a field adjacent to Unit I Porto Ricos, but without replication. There was little crown infestation in either, but at harvest 8 pounds of infested potatoes were culled out of the Triumph and 0.8 pound were culled out of No. 32-106-25. Later, from 50 pounds of each, 10.1 pounds of infested potatoes were culled from the Triumph and 2.8 pounds from No. 32-106-25.

To determine whether weevils preferred the Triumphs or disliked 32-106-25, one potato of each and one Unit I Porto Rico potato were placed in a small cage and 20 adult weevils were introduced. Records were made of the number of weevils and feeding punctures found on each potato at intervals for several weeks. More weevils and feeding punctures were found on No. 32-106-25 than on either of the other potatoes. It appeared, therefore, that any retarding tendency that this seedling might possess must be due to growth characteristics and not to any chemical or food elements. This seedling had a large number of vines branching from the crowns, and the crowns were the hardest and toughest encountered thus far, with definite carotene coloring inside; the roots carrying the potatoes were tough and the potatoes were hard, roundish, and medium-sized, and somewhat scattered in the hills.

In 1943, five seedlings were planted in a latin square and five additional seedlings were planted without replication. This time No. 32-106-25 had more infested potatoes than the others but production was irregular and infestation very light. On a percentage basis this seedling had fewer infested potatoes than the others, but the infestation in the experiment was too light to be of much value.

Ten seedlings were tested in 1944, nine in a lattice square and the tenth adjoining and without replication. Seedling L175 had the fewest infested crowns and L140 had the fewest infested potatoes. L-4-5 had the most infested potatoes, but again the infestation was too light to gain any worth-while comparisons.

In 1945 eight seedlings were grown in a latin square and No. 32-10-5 had the fewest infested crowns and no infested potatoes at all.

In 1946 eight seedlings were again grown in a latin square, and again No. 32-10-5 showed fewest infested crowns and potatoes. This was the first time that any seedling or variety had shown consistent resistance to weevils for two successive years in the presence of sufficient infestation to show significance. This seedling possessed medium-sized and moderately tough crowns and long roots, resulting in a scattering of potatoes in the hill.

The moisture, starch, and carotene content of sweetpotatoes of seedlings and varieties showing the highest and the lowest weevil infestations in the years tested are presented in table 1.

Table 1.—Moisture, starch, and carotene content of sweetpotatoes having the highest and lowest weevil infestations, 1939–1946.

Year	Seedling or Variety	Weevil Infestation	Moisture	Starch	Carotene
		Per Cent	*Per Cent*	*Per Cent*	*Micrograms per Gram*
1939	Menes Moeder	Highest	68.4	21.6	27.6
1940	Menes Moeder	Highest	—	—	—
1941	Unit I Porto Rico	8.0	68.6	21.4	76.2
	L4-5	34.2	61.1	28.9	Trace
1942 a	32-10-5	8.0	74.2	15.8	102.1
	2×16-39-2	43.2	71.2	18.8	—
1942 b	32-106-25	1.6	74.5	15.5	69.7
	Purple Stem Triumph	16.0	67.8	22.2	Trace
1943 a	32-106-25	1.5	—	—	—
	32-94-24	2.5	—	—	—
1943 b	32-10-5	—	73.1	16.9	—
	Menes Moeder	—	65.4	24.6	—
1944	L140	1.0	—	—	—
	L4-5	19.9	60.7	29.3	Trace
1945	32-10-5	0	72.9	17.0	—
	32-94(OPF)43-1	11.4	70.1	19.9	—
1946	32-10-5	1.9	—	—	—
	L127	20.9	64.9	25.1	—

CONCLUSIONS.—The data obtained from the observations reported in this paper indicate the following:

(1) Large, soft crowns or stems are favorable to weevil feeding and breeding.

(2) There appears to be no direct relation between crown infestation and root or potato infestation, although there sometimes appears to be a trend in that direction.

(3) Seedlings and varieties that possess long roots to which potatoes are attached, and which set potatoes scattered in the hill, appear desirable for retarding or preventing weevil attack.

(4) Seedlings 32-106-25 and 32-10-5 possess the above-described characteristics and have shown less weevil infestation than other seedlings and varieties grown in tests with them.

(5) In the six years, from 1941 through 1946, where records are available, sweetpotatoes of the seedlings that showed the lowest infestation were high in moisture and carotene and low in starch content, and, conversely, those that showed the highest infestation were low in moisture and carotene and high in starch content.

(6) There appears to be opportunity for breeding sweetpotatoes with characteristics that will be unfavorable for weevil attack.—1-23-47.

Effect of Concentration of DDT in Oil Aerosols on Toxicity to Mosquito Larvae[1]

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In the course of our researches with the Insecticidal Aerosol generator developed at Columbia University (1946), it became necessary to compare the toxicity of an aerosol composed of non-volatile oil droplets containing 10 per cent DDT by weight with the toxicity of an aerosol composed of supercooled liquid DDT. Using *Aëdes aegypti* larvae as the test insect, results indicate the two differently composed aerosols are of equal toxicity to the larvae.

LARVAL TECHNIC.—Mosquito eggs received from the Entomological Testing Laboratory were placed in a petri dish containing tap water, and kept in a room at a temperature of about 80° F. A very small amount of food (finely ground dog-food) was placed on the water surface. The larvae began emerging a few hours after being placed in the water. The total time which elapsed between the introduction of the eggs in the water and the test was 48 hours.

An hour before the test, 35 larvae were dipped out of the petri dish into each of 16 pint mason jars containing tap water at room temperature.

EXPERIMENTAL PROCEDURE.—The test (May 12, 1945) was carried out in a room 15 by 20 by 10 ft. Room temperature was 55° F. The jars of larvae were placed on a table, the water level brought up to the top of the jars, and the caps replaced.

The generator was placed outside the room and the aerosol was directed into the room through the door for the time calculated to give equal amounts of DDT from two different emulsions. The first emulsion produced the DDT in non-volatile oil droplets containing 10 per cent DDT; the second emulsion produced a highly supersaturated solution containing 55 per cent DDT in an emulsifier.[1] The particle diameter (10 microns) was the same so that equal rates of DDT deposition are obtained.

After the aerosol was introduced into the room, the caps were removed from six jars and replaced after varying lengths of time to give different exposures.

Three control jars were kept sealed on the table in the test room throughout the test period, and one jar was kept in the laboratory.

[1] This paper is based on work done for the Office of Scientific Research and Development under O.S.R.D. Contract No. OEMsr 1388 with Columbia University, Prof. V. K. LaMer, Contract Director.

[2] Authorship includes Irwin B. Wilson, Chemistry Department, College of the City of New York, Kenneth C. Hodges, John C. Rowell, Chemistry Department, Columbia University. These names do not appear for bibliographical reasons.

RESULTS AND DISCUSSION.—The larvae, exposed and unexposed, were left in the test room and examined twenty-four hours after the test. Room temperature was 50° F. The results tabulated below show both types of aerosols were of the same toxicity for practical purposes.

It should be noted however that DDT aerosols produced from volatile oils, such as diesel oils, will probably not be effective against larvae in open fields when the wind speed is above 3 m.p.h. With such winds, evaporation of the oil will most likely reduce the initial particle diameter to a size at which ground deposition in the high wind will not suffice to control larvae for large distances down wind (1946). Such aerosols are, however, practical for field control of adults.

	PER CENT DEAD	
Exposure	*Emulsion 1*	*Emulsion 2*
0.5 min.	95	90
1	100	100
3	100	100
5	100	100
10	100	100
15	100	100
Checks	*Per Cent Dead*	
Test Room	10	
	20	
	15	
Laboratory	10	

CONCLUSION.—DDT aerosols produced from volatile solvents are equally effective as larviciding agents as those produced from non-volatile oils. In field work, however, the initial particle size must be larger than the particle diameter required to give the desired ground deposition with wind speeds greater than 3 miles per hour.

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Leaf-Disk Technique for Laboratory Tests of Acaricides[1]

E. H. SIEGLER, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

Because of their small size, their abundance under favorable conditions, and at times their rapid movement on the host plant, phytophagous mites are difficult to handle in experimental work. To evaluate the acaricidal effectiveness of spray materials, counts to determine mite mortality must be made with a binocular microscope. Therefore it is necessary to choose host samples on which the mite population is small enough so that the mites can be counted with

[1] This article is reprinted from the April issue of the JOURNAL because the illustration was omitted from that issue. Inasmuch as the article deals with technique and the illustrations are a necessary part of the explanatory matter it seems that the reprinting is demanded. EDITOR.

a high degree of accuracy. As a means of conducting tests in the laboratory the writer has devised a method which he has called 'leaf-disk technique.'

To provide a source of mite material the two-spotted mite, *Tetranychus bimaculatus* Harvey, is reared in a greenhouse on bush lima beans. A leaf is removed from the plant and a suitably infested area is placed on a cork cutting block and cut out by means of a short cork borer having a diameter of .87 inch. The leaf disks, usually five per test, are placed in a petri dish, and then removed, one at a time, with forceps and immersed in the stirred test material for a period of 3 seconds. After treatment, the disks are returned to the petri dish, which is provided with moist cotton, and held until examined for counts of mites (nymphs and adults) alive or dead. Ovicidal data can be obtained at the same time if eggs are present.

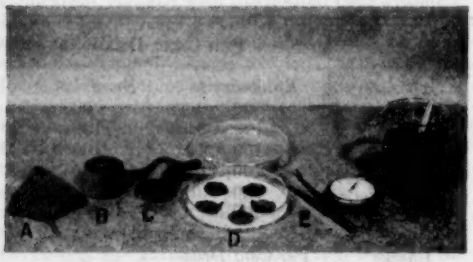

FIG. 1.—Materials and equipment used in leaf-disk technique for laboratory tests of acaricides: *A*, Bean leaf; *B*, cork cutting block; *C*, cork borer; *D*, petri dish with bean-leaf disks and moistened cotton; *E*, forceps; *F*, stop watch; *G*, beaker containing test material.

Table 1.—Typical results obtained with leaf disk technique in laboratoy tests of acaricides.

Material and Dosage (Quantity Per 100 Gal.)	Disk No.	Number of Mites	
		Alive	Dead
Lime-sulfur (conc.), 2 quarts plus *Dreft*, 8 ounces	1	1	11
	2	2	18
	3	0	16
	4	1	17
	5	4	24
	Total	8	86
Dreft, 8 ounces	1	15	3
	2	12	2
	3	22	2
	4	21	1
	5	4	11
	Total	74	19
Distilled water (check)	1	19	4
	2	24	0
	3	19	4
	4	22	1
	5	26	1
	Total	100	10

Certain data selected to illustrate the uniformity of the results obtained with the leaf-disk technique are given in table 1. The disks were immersed on May 22, 1946, and the results were taken two days later.—12-23-46.

Increase of Frosted Scale[1] Following Use of DDT and Other Sprays

W. W. MIDDLEKAUFF, A. E. MICHELBACHER and CLARK SWANSON,[2] *University of California, Berkeley*

A number of investigators have reported serious increases of certain mites and insects following the use of DDT on agricultural crops. Baker & Porter (1945) and Newcomer, Dean & Carlson (1946) report an increase of wooly apple aphid; Driggers (1946), European red mite; Ebeling (1945), citrus red mites and citrus aphids; Gray (1945), two-spotted mite; Loftin (1944), *Aphis gossypii* and *Tetranychus* sp. on cotton; Michelbacher *et al.* (1947), frosted scale and orchard mite; Smith (1945), turnip and cabbage aphids; Wheeler & La Plante (1946), red spider mites; and Woglum (1946), cottony cushion scale.

The present paper contains additional observations on the comparative increase of frosted scale following one and two seasons' use of DDT and other sprays upon Payne walnut trees at Linden, California.

MATERIALS AND METHODS.—The composition of the different materials used, per 100 gallons, was as follows:

DDT.—50 per cent wettable powder, 2 lbs.; light oil emulsion, 0.33 gallon.

DDT+dry nicotine concentrate.—50 per cent DDT wettable powder, 1 lb.; 14 per cent nicotine alkaloid dry concentrate, 1 lb.; DDT depositor, 0.33 lb.; light oil emulsion, 0.33 gallon.

DDD.—50 per cent wettable powder, 2 lbs.; light oil emulsion, 0.33 gallon.

Dianisyl trichloroethane.—25 per cent wettable powder, 4 lbs.; light oil emulsion, 0.33 gallon.

Standard lead arsenate.—3 lbs.; safener (commercial basic zinc sulfate containing 50 per cent zinc); light oil emulsion, 0.33 gallon.

Basic lead arsenate.—4 lbs.; light oil emulsion, 0.33 gallon.

Nicotine-lime dust.—1 quart of nicotine sulfate per 100 lbs. of lime, used at the rate of approximately 1 lb. per tree.

The plot lay-out and methods of application are fully explained in previous publications (Michelbacher *et al.*, 1946 and 1947).

Relative populations of immature scales were determined on December 4, 1946, by counting all live individuals on a 2.5 inch portion of twig of the current season's growth. Ten twigs were selected at random from the skirt of each tree. The 2.5 inch sample to be examined was marked with a knife and then examined under a dissecting microscope in the laboratory. Counts were made during a period of several days and the twigs were placed under refrigeration until examined. To insure greater accuracy, the scales were destroyed as counted.

[1] *Lecanium pruinosum* Coquillett.

[2] The writers wish to thank the following graduate assistants for their help: T. W. Fisher, W. H. Hart, H. T. Reynolds, and W. S. Sibray.

The nicotine dust applications mentioned in tables 1 and 2 were applied for aphid control.

OBSERVATIONS AND RESULTS.—Materials used and scale counts obtained are summarized for the single tree replicated plots in table 1, and for the commercial blocks in table 2.

In the 7 by 7 latin square single tree plot the unsprayed trees averaged 0.3 of an immature scale per twig sample. The trees receiving basic lead arsenate averaged 0.8 scale. Where one spray of 1 pound of actual DDT per season (treatment 3) in 1945 and 1946 was used, the scales averaged 9.3 per twig sample. On the trees receiving two applications of

Table 1.—Effect of various codling moth sprays upon the population of the frosted scale on single tree plots of Payne variety of walnuts.

TREATMENT AND DATES APPLIED	2.5 INCH TWIGS EXAMINED	AVG. SCALES PER TWIG
1. Check (unsprayed)	70	0.3
2. DDT 8 ounces[1] May 4 and standard lead May 31, 1945 DDT 8 ounces plus standard lead 1.5 lbs. May 7 and June 17, 1946	70	2.2
3. DDT 1 lb., May 4, 1945 DDT 1 lb., May 7, 1946	70	9.3
4. DDT 1 lb., May 4 and May 31, 1945 DDT 1 lb., May 7 and June 17, 1946	70	4.0
5. DDD 1 lb., May 7 and June 17, 1946	50	2.0
6. Basic lead arsenate, May 7 and June 17, 1946	50	0.8

[1] Expressed as actual DDT.
All of the above received nicotine dustings on May 11, June 8, and July 30, 1946.

DDT in 1945 and two in 1946, the scale build up was less than half of that in treatment 3, where only one spray per season was used. This may be due to the fact that oviposition begins in May and the young crawlers hatching several weeks later were then present on the leaves and twigs in rather large numbers when the second DDT spray was applied. A number of these may have succumbed to this second spray. Nicotine dusts applied on June 8 and later were observed to cause heavy mortality to young crawlers on the leaves. In treatment 2 where the amount of DDT was reduced to 8 ounces in 1945 and 1946, the build up was considerably less than where one pound was used both seasons.

In the commercial blocks (Table 2) which were contiguous to the single tree plots, the figures are much more surprising. Treatment 1 showed an average of 65.0 scales per twig sample. In an adjacent block (treatment 2) the reduction of the DDT to ½ lb. in the 1946 season plus the addition of 1 lb. of 14 per cent nicotine concentrate still permitted a very heavy build up which averaged 54.9. Treatments 3 and 4 are identical except for one additional nicotine dusting which was applied July 30 to treatment 4. The reduction of scales in the latter may in part be attributed to this application of dust. Two applications of 8 ounces actual DDT plus nicotine concentrate (treatment 6) permitted no

Table 2.—Effect of various codling moth sprays upon the population of the frosted scale on commercial blocks of Payne variety of walnuts.

TREATMENT AND DATES APPLIED	NO. OF 2.5 INCH TWIGS EXAMINED	AVG. NO. OF SCALES PER TWIG
1. DDT 1 lb.,[1] May 4, 1945 1. DDT 1 lb., May 7, 1946 Nicotine dusted June 8 and June 19, 1946	100	65.0
2. DDT 1 lb., May 4 and 31, 1945 DDT 8 ounces plus nicotine May 7, 1946 Nicotine dusted June 8, June 19 and July 30, 1946	100	54.9
3. DDT 1 lb. May 7, 1946 Nicotine dusted June 8 and June 19, 1946	100	15.0
4. DDT 1 lb. May 7, 1946 Nicotine dusted June 8, June 19 and July 30, 1946	100	9.5
5. DDT 8 ounces plus nicotine concentrate 1 lb. May 7, 1946 Nicotine dusted June 8, June 19 and July 30, 1946	100	5.7
6. DDT 8 ounches plus nicotine concentrate 1 lb. May 7 and June 17, 1946 Nicotine dusted June 8 and June 19, 1946	100	0.4
7. Dianisyl trichloroethane 1 lb., May 7, 1946 Nicotine dusted June 8, June 19, and July 30, 1946	215	7.0
8. Standard lead arsenate, May 7, 1946 Nicotine dusted May 11, June 8 and July 30, 1946	50	0.6

[1] Expressed as actual DDT.

increase in the scale population. An analog of DDT, dianisyl trichloroethane (treatment 7) permitted a build up to an average of 7.0 scales per twig. A block receiving standard lead arsenate averaged 0.6 scales per twig.

DISCUSSION.—While conceding that spontaneous flare-ups of various insect pests are not unusual, recent data show numerous examples of increases of certain insects and mites following the use of DDT. Counts of adult scales were made on May 10, 1946 after one season's use of DDT (Michelbacher *et al.*, 1947) and were used to establish the population base for late season build up.

To date, not enough information is available to explain the reasons why DDT permits the frosted scale to increase. It is conceivable, however, that the use of DDT materially reduces the population of parasites and predators which normally hold it in check.

The difference in scale build up between the 7 by 7 individual tree plots and the large commercial blocks may well indicate the effect of DDT upon the natural predators and parasites. In the single tree plots, adjacent non-DDT treatments could have supplied sufficient predators and parasites to permit

a partial suppression of scales. The commercial blocks receiving corresponding treatments were much more insulated, and may indicate what might happen where DDT is used on a large commercial scale. At least in these investigations, the severity of the scale infestation increased when the treatments were applied on a commercial scale. A speculation of this effect has also been suggested by Newcomer *et al.* (1946).

SUMMARY.—Results of two seasons' application of DDT and other spray materials for control of codling moth on Payne walnuts at Linden, California, permitted a considerable build up of the frosted scale. Immature scales were counted and results of various treatments compared. Check trees and trees receiving standard or basic lead arsenate averaged from 0.3 to 0.8 scales per twig, while those trees which received DDT 1 pound actual in 1945 and again in 1946 averaged for the single tree plot 9.3 scales and for the commercial blocks 65.0 scales per 2.5 inch twig sample. Two sprays of DDT 8 ounces actual plus 1 pound of 14 per cent dry nicotine concentrate held the scales to an average of 0.4 in the commercial blocks.

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Thermal Decomposition of DDT Dispersed in Water[1,2]

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A number of factors influence the toxic effects of an insecticide when tested as an aqueous dispersion against mosquito larvae. Bacterial contamination is one factor which is seldom controlled. In connection with toxicity studies using pure DDT [2,2-bis (p-chlorophenyl) 1,1,1-trichloroethane] an autoclaved DDT dispersion was found to be at least 40 per cent less toxic than a dispersion kept at room temperature. This marked loss in toxicity of autoclaved DDT dispersions was the stimulus for chemical studies to explain such a difference. Fleck & Haller (1946) found a catalytic removal of hydrogen chloride from DDT using 0.01 per cent anhydrous ferric chloride and other catalysts at temperatures ranging from 110° to 120° C., but in the absence of catalysts pure DDT (m.p. 108.5° to 109.5° C.) under dry conditions does not decompose until temperatures of 140° to 145° C. (West & Campbell 1946) or 195° C. are attained (Balaban & Sutcliffe 1945).

Table 1.—Treatments of DDT and results.

TREATMENT	NUMBER OF TRIALS	PERCENTAGE DDT DETERMINED	
		Range	Average
None	9	71–95	88
Autoclaved *ca.* 15 lbs. 15–20 minutes	5	12–74	40.4
Boiled 15–20 minutes	6	0–12	7.5
Heated (88–97° C.)	3	26–40	34.8
Heated (80° C.)	1	88.5	88.5
HCl, 0.1 N	1	81.9	81.9
HCl, 0.1 N, boiled 20 min.	1	5.4	5.4
NaOH, 0.1 N	1	60.2	60.2
NaOH, 0.1 N, boiled 20 min.	1	0.0	0.0
Aerated 2 hours	1	92.3	92.3

EXPERIMENTAL.—The colorimetric determination of DDT (Schechter *et al.*, 1945) was employed with readings being made on a *Coleman Model 11* spectrophotometer .A purified sample of DDT (m.p. 108.6° to 109.5° C.) was dissolved in C. P. acetone and added to double distilled water at the rate of 1 p.p.m. (0.1 per cent acetone). C. P. benzene extracted DDT from the water for determinations. After the solvent was driven off on a steam bath the DDT residuum was nitrated and carried through to color development (Schechter *et al.* 1945). Blanks with 0.1 per cent acetone were run simultaneously.

RESULTS AND DISCUSSION.—A definite chemical

[1] Paper No. 2293 of the Scientific Journal Series, Minnesota Agricultural Experiment Station, St. Paul, Minnesota.

[2] The work described in this paper was begun under a contract, recommended by the Committee on Medical Research, between the Office of Scientific Research and Development and the University of Minnesota. It was completed under a similar contract between the Medical Division of the Chemical Warfare Service and the University of Minnesota. Advice and interest given by A. G. Richards, Responsible Investigator, is greatly appreciated.

decomposition of DDT occurred when used as a 1 part per million dispersion in distilled water and heated to 90° C. and above (see table and graph). Pressures of autoclaving ranged from 13 to 17 lbs. corresponding to a 121° C. average. DDT recoveries from autoclaving varied from less than 25 per cent (3 trials) to over 60 per cent (2 trials), while 15 to 20 minutes boiling produced samples of 12 per cent or lower DDT content. Recovery was satisfactory at 80-85° C. An alkali media gave the expected DDT loss while DDT appeared stable in the acid medium.

A study of the color curves produced under the various treatments gave evidence of the expected mixed DDT and dehydrochlorinated p,p'-DDT [2,2-bis (p-chlorophenyl) 1,1-dichloroethylene] under alkaline conditions (in vitro studies of White & Sweeney 1945). However, the autoclaved and boiled samples did not appear to yield dehydrochlorinated p,p'-DDT, p,p'-DDA [bis (p-chlorophenyl) acetic acid], bis (p-chlorophenyl) methane, or 4,4'-dichlorobenzohydrol since these compounds give reddish colors under this treatment (Schechter *et al.*). There is some indication that the decomposition products resulting from boiling and autoclaving are different compounds. It is conceivable that low DDT recovery values could be due to volatilization under boiled treatment but this explanation is unlikely with autoclaved and sub-boiled samples.

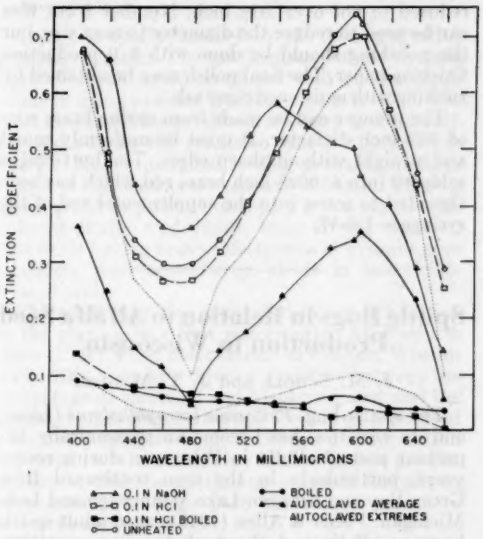

FIG. 1.—Absorption curves representing the polynitro compounds of DDT and decomposition products after a DDT dispersion in water has been subjected to the various treatments listed. Values are averages except where single determinations were made (see table).

Two experiments with aerated samples revealed no chemical breakdown after 2 hours treatment, but DDT was no longer evenly distributed in the aqueous media. A pipetted sample yielded only one-third the DDT extracted from the sides and bottom of the flask. Visual observation of an old and a well aerated sample discloses a number of DDT particles on the bottom of the flask. Chemically, DDT appears unchanged but an aerated or aged dispersion would be less toxic to organisms because of the physical alteration of the DDT dispersion.

SUMMARY.—A dilute DDT dispersion in water heated above 90° C., boiled or autoclaved, decomposes chemically. The breakdown products were not determined, but it is possible that those resulting from heating or boiling are distinct from autoclaved breakdown compounds. Under these experimental conditions none of the compounds having a maximum in the 520 to 560 millimicron range (reddish colors) are evident. This includes dehydrochlorinated p,p'-DDT and DDA. Aerated and aged dispersions showed no chemical breakdown of DDT, but a physical change took place in that DDT was more concentrated at the bottom and sides of the flask.—1-18-47.

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A Syringe for Artificial Insemination of Honeybees

WILLIAM C. ROBERTS, *University of Wisconsin,*[1] *Madison*

The establishment of improved lines of honeybees has long been delayed because of the inability of the beekeeper to control matings. A solution to this problem has been found in artificial insemination. In recent years this technique has been improved through better instruments and increased knowledge of honeybee morphology and physiology.

In place of the glass-tipped syringe used by earlier investigators, the author now used one made of the clear plastic *Lucite*.[2] A *Lucite* tip is superior to glass because it is not easily broken, sharp edges are eliminated, and it can be machined and drawn to the desired diameter and bore. Threaded replaceable tips can be readily changed and are easily cleaned. *Lucite* does not have the surface hardness of glass and consequently will wear slowly. It should not be boiled for cleansing since *Lucite* tips soften and distort when boiled in water. The plastic tips can be cleaned with mild soap and water. Grease and oils are removed with hexane, naphtha, or methanol. A

[1] In cooperation with the Division of Bee Culture, Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture.

The author wishes to thank Mr. L. K. Henke, Mechanician in the Department of Chemistry, for his excellent suggestions in the construction of this instrument and the privilege of using the machine-shop facilities.

[2] Product of the E. I. du Pont de Nemours & Company (Inc.).

quick rinse in ethyl alcohol will sterilize tips. However, the should not be left in alcohol since it slowly dissolves the plastic.

The machining qualities of *Lucite* and brass are quite similar. Since this plastic is a poor conductor of heat, it is necessary to prevent overheating when drilling, cutting, or polishing. Drills should be lubricated with mineral oil or an oil solution (2 per cent soluble oil in water). Frequent removal of chips is necessary when drilling deep holes, and the hole is filled with the oil solution at each removal of the drill. Sharp drills and proper lubrication give uniform and polished inside walls to the tip. This results in good suction without the necessity of a lubricant when picking up sperm.

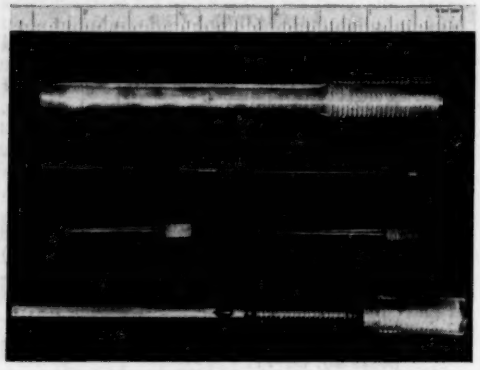

FIG. 1.—Parts of the syringe showing extra tip and plunger.

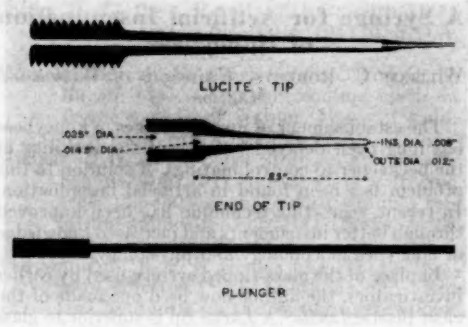

FIG. 2.—Structural details of the tips and plunger.

All of the syringe parts are shown in figure 1, and the structural details of the tips and plunger are given in figure 2. Since the measurements and details of construction of the barrel, turning screw, couplings, and supplemental rod are of secondary importance, they will not be described. Their approximate size can be ascertained from the picture and operators will doubtless alter these parts to fit their own syringe holders and accessories. The universal joint between the turning screw and the supplemental rod allows the metal plunger to move within the tip without the rotation of the turning screw. This reduces wear and aids in giving better suction.

The tip is made from a *Lucite* rod of .1875-inch diameter. This is placed in the machine and drilled for about 1 inch with a No. 72 (.025 inch) drill. A smaller drill—No. 79 (.0145 inch)—provided with a long shank is then used to drill an additional .1 inch in the bottom of the .025-inch drilled hole. The outside diameter is then turned down to .164 inch and the end threaded for a distance of about .25 inch with an 8-32 threading die. Before removing the rod from the machine, its diameter between the threaded portion and the end of the drilled portion can be reduced to the approximate size of the main portion of the tip (.085 inch).

The end of the tip containing the small hole is then uniformly heated by rotating on an electric soldering iron until it becomes soft enough to stretch. This .1-inch section with the .0145-inch diameter bore is then stretched to a length of .2 to .25 of an inch and while still held taut it is hardened in cold water. If properly heated, the .025-inch diameter hole is not distorted. The .0145-inch drilled hole becomes a gradual taper from that diameter down to less than .008 inch. The end of the tip is then filed off square and the outside diameter reduced to not over .012 inch. Number 2 cut files can be used to reduce the diameter to near size, but the polishing should be done with 9/0 production finishing paper. The final polish may be obtained by rubbing with moistened cigar ash.

The plunger can be made from spring brass wire of .025-inch diameter. It must be uniformly round and straight without sharp edges. The butt end is soldered into a .0625-inch brass rod which has been threaded to screw into the supplemental rod of the syringe.—1-6-47.

Spittle Bugs in Relation to Alfalfa Seed Production in Wisconsin[1]

J. M. SCHOLL and J. T. MEDLER[2]

The spittle bug, *Philaenus leucophthalmus* (Linn.) and its varieties, has become an economically important pest of alfalfa in Wisconsin during recent years, particularly in the area southward from Green Bay and between Lake Winnebago and Lake Michigan. Fisher & Allen (1946) caged adult spittle bugs on alfalfa and observed dwarfing, rosetting, blossom blasting, and necrosis of foliage following approximately one month of feeding. The damage in cages was not so great as that caused by feeding of nymphs which had been observed in the field earlier. Additional observations have been made by us in conjunction with alfalfa seed experiments and are reported below.

Philaenus leucophthalmus is represented in Wisconsin by all of the eight varieties listed by Doering (1930). The identification of varieties was made from a sample taken from a total of 60,919 adults that were collected in connection with insect population studies in alfalfa fields during the summer of 1946. Collections in two areas of the state were grouped separately, and 1812 and 1479 specimens respectively were sampled for identification in the two areas. Table 1 gives the relative percentages

[1] This work was supported in part by a grant from the Wisconsin Alumni Research Foundation.

[2] Research assistant and assistant professor respectively in the Departments of Economic Entomology and Agronomy, University of Wisconsin.

of the different varieties in the areas. The most common varieties are *P. pallidus*, which is uniformly yellow or yellowish-brown, and *P. spumarius*, which is yellow- or fuscous-brown with two light colored spots on the costal margin of the forewing.

Table 1.—Distribution of varieties of *Philaenus leucophthalmus* in Wisconsin alfalfa fields in 1946.

Variety	East-Central Area Per Cent	South-Central Area Per Cent
P. fabricii Van Duzee	11.6	14.2
P. fasciatus (Fabr.)	1.6	1.4
P. lateralis (Linn.)	2.8	2.3
P. leucocephalus (Linn.)	0.1	—
P. leucophthalmus (Linn.)	2.1	1.6
P. marginellus (Fabr.)	—	0.1
P. pallidus (Zett.)	39.8	30.3
P. spumarius (Fall.)	42.3	50.1

Injury to alfalfa results from the feeding of either nymphs or adults. The spittle masses of the nymphs were observed on 75 to 99 per cent of the alfalfa stems in many eastern Wisconsin fields in 1946. The most characteristic symptom of injury is the dwarfing and bunchy-top condition that is illustrated in figure 1. Heavy nymphal feeding probably weakens the plant and lessens the amount of bloom. There is also a possibility that this injury is correlated with reduced alfalfa seed yields, since it was observed that fields having heavy infestations of nymphs gave relatively poor second-crop yields in insecticide-treated plots.

The adult may also cause seed injury in addition to the plant injury that was reported by Fisher & Allen (1946). Field observations at Chilton, Wisconsin in 1945 showed a direct correlation between the percentage of shriveled and blackened seed and the extent of adult puncturing and feeding on green seed pods and immature seed. Although pod formation appeared to be normal, very little seed was present at harvest and the spittle bug injury is thought to have caused in large part the almost complete failure in seed yield.

Seed injury was further investigated in 1946. Screen cages about 6 inches in diameter and 2 feet high were placed over alfalfa plants when they were through flowering but while the seed pods were still green. About a dozen adult spittle bugs per plant were placed in the cages, and an uninfested cage was kept as a check. The seed was examined for injury when the pods were mature. It was found that 50.5 per cent of the seed in the infested cages was shriveled, while only 18.6 per cent of the seed in the check cage was shriveled. More detailed studies are planned to further clarify the nature of the feeding injury described above.

The spittle bug should be controlled in the nymphal as well as the adult stage in fields that are to be used for seed production. The insecticidal control of adults only without control of the nymphs is not satisfactory in localities where large populations are present and migration into alfalfa can take place from various other host plants. A preliminary experiment for the control of nymphs was made in 1946 with sabadilla, nicotine and rotenone as sprays and dusts in randomized plots in two replicates.

FIG. 1.—Spittle bug injury to alfalfa by nymphal feeding. The stem at the left is normal, those on the right show the characteristic dwarfed and bunched appearance of infested stems.

DDT was not tested in this experiment because plots were laid out where the alfalfa was cut for hay. The percentage of infestation was based on a count of alfalfa stems with spittle masses in a sample of 100 stems per plot, selected at random, since it is difficult to estimate populations of nymphs by ordinary sweeping methods. The infestation was 82.5 per cent at the time the insecticides were applied on June 13. Table 2 gives the infestation count one week later. It appears that none of the insecticides gave significant control. Mundinger (1946) reported that 1% rotenone dust was effective as a control measure for nymphs in New York, and stated that the proper timing of treatment is an important factor in control. Further experiments to test other insecticides and time of application are planned for Wisconsin.

The value of insecticides in controlling adult spittle insects appears to be uncertain. In 1945, 5 per cent DDT and 10 per cent sabadilla were used as dusts on seed plots near Chilton. Table 3 shows the relatively large populations present, and the downward trend in all plots suggests natural mortality rather than an insecticidal effect. A seed yield of 8, 3, and 2 lbs. for the DDT, sabadilla, and untreated plots, however, suggests that there may have been some control of the spittle bugs which was not indicated by the sweeping.

In 1946 a trap strip was tried for the control of spittle bugs and other injurious insects in alfalfa seed plots. A 28-foot swath was cut lengthwise through a 7-acre field on June 20. On July 5, when the swath showed about 6 inches of new growth, the remainder of the field was cut. Spittle bugs and other insects migrated during this time into the succulent new growth in the trap strip. The trap strip was dusted with 5 per cent DDT at the rate of 70 lb. per acre on July 8. The number of adult

Table 2.—Effects of dusts and sprays on occurrence of spittle masses in alfalfa plots in 1946.

Treatment	Plot Per Cent	Average Per Cent	Per Cent Reduction from Check[1]
Untreated check	84.0		
	80.0	82.0	—
Sabadilla spray	76.0		
2 lbs. in 100 gal. per acre	58.0	67.0	18.3
Sabadilla dust	86.0		
10% at 40 lb. per acre	82.0	84.0	—
Nicotine spray	84.0		
1 to 400 at 100 gal. per acre	64.0	74.0	9.8
Nicotine dust	90.0		
3% at 40 lb. per acre	72.0	81.0	1.2
Rotenone spray			
9 lbs. of 4.4% rotenone	58.0		
at 100 gal. per acre	72.0	65.0	20.8
Rotenone dust	80.0		
1% at 40 lb. per acre	50.0	65.0	20.8

[1] No significant differences at 5 per cent level.

spittle bugs just prior to dusting averaged 10 per sweep with a 12-inch insect net. The next day only 1 spittle bug per sweep was found. No other treatment was given to the field. The seed harvest from the trap strip was 320 lbs. per acre, while the average yield from the remainder of the field was 132 lbs. per acre. Under these conditions it appears that 5 per cent DDT may effectively reduce the numbers of adult spittle bugs. The difference in yield between the trap strip and untreated part of the field perhaps can be explained by the residual action of DDT on other injurious insects, and the difference in time of cutting.

Observations reported above have shown that spittle bugs are economically important in many Wisconsin alfalfa fields. The feeding of nymphs and adults causes a characteristic bunchy-top condition of the plants. The feeding of adults on immature seed pods also may be a factor in alfalfa seed production since it results in shriveled seed. A trap strip treated with 5 per cent DDT appeared to reduce the numbers of adults in an alfalfa field left for seed production, but further experimental work is needed in order to determine the time and rate of application of an insecticide that can be used as a control measure for nymphs. Furthermore, when a forage crop is treated with DDT consideration must be given to the possible hazard of DDT remaining on or in the forage at the time of feeding.—1-2-47.

Table 3.—Spittle insect populations in alfalfa plots at Chilton, Wisconsin in 1945.

Treatment	Average Number of Adults per Sweep — Dates					
	July 31	Aug. 2	Aug. 16	Aug. 24	Sept. 9	Sept. 17
Untreated check	33	24	18	12	10	4
DDT dust, 5% at 18 lb. per acre		13	10	8	8	3
Sabadilla dust, 10% at 25 lb. per acre		16	14	8	9	3

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Trap Strips to Control Insects Affecting Alfalfa Seed Production[1]

J. M. Scholl and J. T. Medler[2]

That the destruction or removal of insect food may cause subsequent migration of insects to adjacent food plants is well known to entomologists. The use of a trap crop that attracts large numbers of insects to small areas where more efficient and more economical control measures may be applied has been successful in controlling certain insects such as the cotton boll weevil, the pickle worm and the harlequin cabbage bug.

A trap strip which represents a combination of the above principles has been tried in Wisconsin for the control of injurious insects that are a factor in alfalfa seed production. The preliminary results are being reported at this time.

In 1945 a trap strip 15 feet wide was cut lengthwise through the center of a small field (74 by 272 feet) on June 15. It was observed that insects left the stubble which contained only a limited amount of food and concentrated in the uncut areas adjacent to the strip. On June 25 the remainder of the field was cut. At this time the succulent second growth during the 10-day period in the trap strip was very attractive to alfalfa-feeding insects and migration into it soon took place. Ten days later the trap was dusted with 10 per cent DDT at the rate of 25 pounds per acre. Table 1 gives a summary of the insect counts. The counts show that the numbers of three injurious species of insects were reduced in the trap strip by action of the DDT, and in the remainder of the field by migration into the trap.

In another trial in an adjacent field of approximately the same size a trap strip was left uncut when the remainder of the field was cut on July 6. This trap was also dusted with 10 per cent DDT. The insect counts are given in table 2. These data likewise show a reduction in the numbers of insects in the field, through insect migration and action of DDT.

The work in 1945 indicated that in small areas an insect migration of considerable magnitude took place. This suggested that perhaps injurious alfalfa insects could be controlled by insecticides without

[1] This work was supported in part by a grant from the Wisconsin Alumni Research Foundation. The authors wish to acknowledge the help of L. F. Graber who first suggested the use of the trap strip in alfalfa.

[2] Research assistant and assistant professor respectively in the Departments of Economic Entomology and Agronomy, University of Wisconsin.

Table 1.—Number of nymphs and adults of three species of insects in an alfalfa field with an early-cut trap strip at University Hill Farm, Madison, Wis. in 1945.

Treatment	Date Sampled	Number of Insects in 12 Sweeps of a 15" Insect Net		
		Adelphocoris lineolatus	*Lygus oblineatus*	*Empoasca fabae*
Trap Strip—Cut June 15	July 3	7	51	42
Remainder of Field—Cut June 25	July 3	0	4	4
Trap Strip—24 hours after dusting with 10% DDT	July 7	0	0	1
Remainder of Field—No treatment	July 7	0	8	30

Table 2.—Number of nymphs and adults of three species of insects in an alfalfa field with a delayed-cut trap strip at University Hill Farm, Madison, Wis. in 1945.

Treatment	Date Sampled	Number of Insects in 12 Sweeps of a 15" Insect Net		
		Adelphocoris lineolatus	*Lygus oblineatus*	*Empoasca fabae*
Trap strip—Not cut	July 10	1	108	147
Remainder of Field—Cut July 6	July 10	2	3	9
Trap Strip—48 hours after dusting with 10% DDT	July 14	0	2	4
Remainder of Field—No treatment	July 14	1	5	29

treating the entire field. This can be an important consideration when a forage crop is treated with DDT or similar insecticides that may leave a hazardous residue on the forage.

Experiments were conducted in 1946 in four alfalfa fields in east-central and south-central Wisconsin on the control of insects by dusting early-cut trap strips.

Field 1 was a 7-acre alfalfa field in Calumet County. On June 20 a strip 24 feet wide and 700 feet long was cut through the field 150 feet from the east side. The remainder was cut July 5. The trap strip was dusted on July 8 with 5 per cent DDT at the rate of approximately 70 lbs. per acre.

Field 2, in Manitowoc County, consisted of 4 acres. The trap strip 28 feet wide and 600 feet long was cut about 100 ft. from one side on June 15. The remainder of the field was cut on July 2. A 5 per cent DDT dust was applied at the rate of approximately 50 lbs. per acre to the trap on July 6.

Field 3, in Sheboygan County, was approximately 3 acres in size, but adjacent to a large field of alfalfa that was kept for forage. The trap strip was 54 feet wide and 175 feet long, and was cut on June 15. A 5 per cent DDT dust was applied at the rate of approximately 50 lbs. per acre on July 5. The remainder of the field was cut on July 8.

Field 4 in Jefferson County was a rectangular field with an area of 9 acres. The trap strip 40 feet wide and 400 feet long was cut about 150 feet from one end on June 7. The part of the field adjacent to the trap was cut on June 15, but most of it was left uncut until after the trap was dusted with 5 per cent DDT at the rate of 40 lbs. per acre on June 20.

Dusts were applied with a self-propelled duster, except for the trap in field 4 which was dusted with hand dusters. The number of injurious insects in the

Table 3.—Number of nymphs and adults of four species of injurious insects in alfalfa fields with trap strips in Wisconsin in 1946.

Field No.	Date Sampled	Average Number of Insects per Sweep			
		Lygus oblineatus	*Adelphocoris* spp.	*Empoasca fabae*	*Philaenus leucophthalmus*
1	June 15—Trap before cutting	0.05	7.77[1]	0.09	0.75
	July 8—Trap before dusting	0.24	0.47	0.77	9.86
	July 9—Trap after dusting	0.03	0	0	1.37
2	June 14—Trap before cutting	0.04	12.68[2]	0.19	0.04
	July 6—Trap before cutting	1.12	1.00	1.60	63.77
	July 8—Trap after dusting	0.27	0.12	0.07	7.35
	July 24—Trap	1.52	0.22	2.77	7.75
	July 24—Untreated	0.95	0.40	0.85	17.22
3	June 13—Trap before cutting	0.01	0.79	0.02	0.73
	July 5—Trap before dusting	0.28	1.16	22.83	0.12
	July 25—Trap after dusting	1.02	0.20	1.95	31.55
	July 25—Untreated	0.26	0.28	1.96	11.73
4	June 6—Trap before cutting	0.14	2.06	0.01	0.05
	June 19—Trap before dusting	0.07	0.51	0	0.06
	June 25—Trap after dusting	0.09	1.11	0.06	4.45
	July 22—Trap	3.67	0.50	2.12	2.37
	July 22—Untreated	3.95	0.96	0.73	3.95
	August 14—Trap	1.27	0.55	0.07	0.57
	August 14—Untreated	3.71	1.33	0.37	1.08

[1] 7.6 insects of this sample were nymphs.
[2] 12.6 insects of this sample were nymphs.

plots was usually estimated by 100 sweeps with a 12-inch insect net. Counts of injurious insects were made before the trap was cut, before the trap was dusted, and after the trap was dusted. Table 3 summarizes these data for *Lygus oblineatus* (Say), *Adelphocoris lineolatus* (Goeze), and *Adelphocoris rapidus* (Say) combined, *Empoasca fabae* (Harris), and *Philaenus leucophthalmus* (L.) and its varieties combined.

These data show that there was a reduction of total insects in the trap in fields 1 and 2 after dusting but an increase in fields 3 and 4. This descrepancy may perhaps be explained by the fact that the insecticide was applied to the trap in field 3 before the remainder of the field was cut. In field 4 more than half of the field also was uncut when the dust was applied. Much of the difference in fields 3 and 4 is caused by the relatively large number of spittle bugs that moved into the traps after dusting. These showed no apparent effect from the insecticide at the time the sample was taken. In field 4 the counts subsequent to dusting gave fewer total insects in the trap than in the remainder of the field at approximately 1- and 2-month intervals.

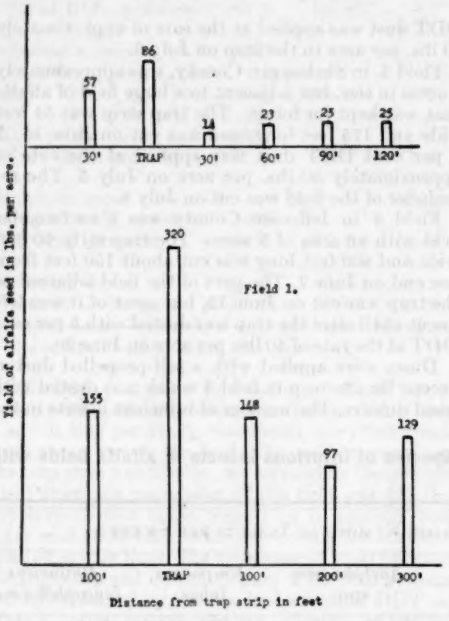

FIG. 1.—Seed yields in the trap strip and at intervals from the trap strip in two fields of alfalfa in 1946. (Field 4 is the narrow area above the line over the larger area labeled Field 1.

In the trap strip experiments it was realized that a suitable check plot could not be kept until the size of the zone of attraction by the trap was determined. Theoretically a ratio might exist between the yield of seed and the distance from the trap—the area closest to the trap showing the highest yield. Data were taken in fields 1 and 4 in order to test this relationship.

A sample was taken for seed yield in the center of the trap strip and at regular intervals in the untreated portion on each side of the trap. The samples were taken from strips 100 feet long and 34 inches wide which were cut parallel to the trap. Figure 1 gives the distribution of seed yields in the two fields. It was demonstrated that under the conditions of this experiment no significant difference in yield occurred in the strips in the untreated part of the field. The low seed yield in field 4 can be explained in part by the drought in the area where this field was located.

The seed yields of the trap strips and an average yield of the remainder of the fields are given in Table 4. The trap strip produced a much higher yield of seed than the untreated portion in all fields. This perhaps can be explained by the residual effect of the insecticide, or the longer time available for plants within the trap to bloom and mature seed. There also is a possibility that pollinating insects were concentrated on the trap before the rest of the field came into bloom. Some areas of Wisconsin experienced drouth conditions in the latter part of the summer of 1946 and the early cutting of the trap may have enabled it to escape severe drouth injury. Moisture conditions also may have been a factor in the variation that took place in seed yields between the different localities.

Table 4.—Comparison of seed yield in trap strips and untreated parts of four alfalfa fields in Wisconsin in 1946.

Field No.	Average Yield in Pounds of Seed per Acre	
	Trap Strip	Untreated Part of Field
1	320	132
2	78	38
3	12	5
4	86	29

The preliminary experiments reported above have shown that a strip of new-growth alfalfa in a field at the time of cutting attracts injurious insects. The reduction in numbers of injurious insects in an alfalfa field by dusting the trap with DDT may be a factor in increased seed production, but the effective area of attraction by the trap has not yet been determined. Further investigations are planned in order to establish the proper balance of area between the trap and untreated part of alfalfa fields.—1-2-47.

Infestation of a Raccoon by *Amblyomma americanum*

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While examining a raccoon pelt a reddish spot was noticed on the superfacial fascia near the right ear. This animal was trapped by Mr. Walker Powell of Reeds Spring, Missouri in early December, 1946. By carefully removing a thin layer of the fibrous connective tissue, the red spot was found to be a female long star tick, *Amblyomma americanum*.

This is the second infestation of this type recorded from Missouri by this tick. The first record was of a red fox in January, 1945 which had over 150 embedded ticks.

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Hog Mange Control Tests[1]

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The desperate need for a satisfactory and acceptable control for hog mange *Sarcoptes scabiei suis* Megn. prompted the tests reported in this paper. The controls now generally recommended are lime sulfur and various preparations of coal-tar creosote or petroleum oil. These materials have not been satisfactory to the grower because of difficulty in handling, the necessity of making several applications at short intervals, and the chance of injury to the animals. Caler (1931) found that a special 20 per cent oil emulsion gave no control of hog mange. Gapuz (1940) reported complete control of horse scabies with a 2.5 per cent infusion of fresh derris root applied twice at 24-hour intervals. The rotenone content was not stated. Gordon & Unsworth (1942) reported low mortality to *Notoederes* sp. and *Sarcoptes scabiei hominis* with 5 per cent benzyl benzoate. Slepyan (1944) reported complete clean-up of *S. scabies hominis* with a 25 per cent benzyl benzoate emulsion. Slade (1945) reported that benzene hexachloride was lethal to poultry red mite. These reports offered no more than a hope in solving the hog mange problem.

FIG. 1.—Spraying hogs for mange showing tendency to crowd and pile up.

The tests reported in this paper were on a herd basis without regard to size or age of the animals. All of the materials used were liquid sprays applied at 200 to 225 pounds pressure with an orchard gun equipped with a 5 mm. disc opening. About 3 quarts of spray were used per animal. The hogs were sprayed in small pens or sheds so as to get close enough to wet them completely. Particular effort was made to spray into their ears. Their tendency to pile up gave complete wetting of the underside. The toxicants were benzene hexachloride wettable powder,[3] benzyl benzoate 98 to 100 per cent[4] emulsified with *Triton X-100*,[5] DDT emulsion (*Deenol*),[6] and a patented brand rotenone extract emulsion[7] containing approximately 5 per cent rotenone used according to the directions on the container. To determine the presence of mange mites, scrapings were made before the infested animals were sprayed. After being sprayed, herds were examined and scrapings were made at approximately 2-week intervals. Table 1 shows the results of the tests in 12 herds.

Table 1.—The results of spraying mange-infested hogs with certain chemicals.

CHEMICAL	PER CENT TOXICANT BY WEIGHT[1]	NUMBER OF HERDS	NUMBER OF HOGS	RESULTS[1]
Benzene hexachloride[1]	0.082	1	17	No control
Benzene hexachloride	0.25	3	195	No mites
Benzene hexachloride	0.50	2	118	No mites
Benzyl benzoate	0.50	2	72	Mites present
DDT emulsion	0.50	2	157	Mites present
Rotenone extract	?	2	193	Mites present

[1] Percentage toxicant of benzene hexachloride indicates gamma isomer.

Higher concentrations of the various materials were not tested since the benzene hexachloride was tested first and was giving complete clean-up at 0.25 and 0.50 per cent with one application. Into one herd, sprayed September 27 and found free of mange on October 17, six unsprayed infested animals were introduced October 25. On December 3 there were initial lesions of mange in the herd.

Results of these preliminary tests indicate that benzene hexachloride is a most promising control material for hog mange. Even with its musty, persistent odor and its irritation to the operator, it has superior points. The one application clean-up is most important. The low toxicity to the animals and the very good possibility of lice control make the chemical worthy of extensive testing. The low percentage of the toxicant necessary for control indicates an economical spray.—2-10-47.

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[1] Published with approval of the Director as Paper No. 410 Journal Series, Nebraska Agricultural Experiment Station.

[2] Dr. A. G. Beagle, Bureau of Animal Industry of the United States Department of Agriculture, made the scrapings and analyses on all herds sprayed. The final results contained in this report are based on his work and the authors are most grateful to him for this contribution.

[3] Supplied by Pennsylvania Salt Manufacturing Company.

[4] Supplied by Merck & Company, Inc.

[5] Supplied by Rohm & Haas.

[6] Supplied by E. I. DuPont de Nemours Company.

[7] Supplied by W. T. Spencer, National Live Stock Loss Prevention Board.

Effect of DDT on Populations of Codling Moths

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Effect of DDT on adult codling moth reduction was studied at the Hood River Branch, Oregon Experiment Station, in 1946. Moth performance was observed in two 8-acre blocks of orchard; one sprayed with DDT the other with lead arsenate. The areas were located approximately 200 yards apart. The DDT area received, for the most part, 1 pound actual DDT to 100 gallons of water in the first cover. In the second cover, half of the area received 1 lb. —100 DDT and the balance, with minor exceptions, 8 oz. to 100 gallons. Six cover sprays of 3 lbs. to 100 gallons were applied in the lead arsenate area. A calyx spray of 3 to 100 was used in both blocks. In this test the DDT was applied with maximum care. All portions of the trees were covered including lower leaf surfaces, so that there would be present no unsprayed surface upon which the moths could rest. Nonfruiting trees were likewise sprayed.

Ten traps, baited with *Di-malt* (1 pt. to 16 pts. of water plus a small amount of yeast), were set up in each area. The traps where the DDT was employed were established at the beginning of moth flight. The traps in the lead arsenate sprayed area were established at the time of the first DDT application, or on May 28. Traps have been maintained in the station orchard for the past 15 years. The moth take from 10 traps has ranged from 3 to 5 thousand moths annually. The moth take in the lead arsenate area for 1946 was quite typical of previous performance.

Moth records were taken at 2-day intervals. Effects of the DDT on the moth population were highly significant. The first spray was applied at the peak of the seasonal moth population in the orchard; 36.5 per cent of the yearly moth emergence had occurred. At the time of spraying and for several days thereafter, evening temperatures were low, resulting in limited moth take in all traps. The first period of favorable weather for moth flight following spraying occurred 4 days later. Seventeen moths were taken in the DDT block and 295 in the lead arsenate area; a reduction of 94.3 per cent. During the following 2-day period, the ratio was 2 and 110 moths or a reduction of 98.2 per cent. This type of reduction prevailed throughout the season. The total moth catch for the balance of the year following the DDT spray, applied on May 28 and repeated July 23 was 183 moths; during the same period 2831 moths were taken in the lead arsenate area. The reduction was 93.6 per cent. If full value is given moths present in the orchard at time of spraying, the percentage reduction for the season amounted to 95.9 per cent. Where DDT was used, there occurred 46 days during the period of moth activity when no moths were caught; in the regularly sprayed block there were 14 such days. No dead moths were found on the ground in the orchard following spraying or at other times of examination. Numerous species of other insects were found dead under the trees, these were particularly noticeable the day after spraying. On several occasions, evening moth flight was noted to be extensive in the lead arsenate area, while at the same time it was slight or absent in the DDT-sprayed section of the orchard. In the DDT-sprayed area where 1 pound of DDT was used in 2 applications, fruit condition at harvest time was as follows; wormy, 0.52 per cent; stung 4.4 per cent; fruit free from worm damage 95.2 per cent. The following condition was found in the lead arsenate sprayed area: wormy 4.5 per cent; stung 51.3 per cent; apples free from worm damage, 46.9 per cent.

It is believed that mass reduction of moths—an accomplishment unobtainable through the use of former insecticides employed—contributed to the highly satisfactory results obtained. Evidence gathered over a period of 3 years indicates that small plot tests, although resulting in a high degree of worm control, do not express the full value of DDT such as follows complete orchard spraying or that which would follow grower practice. Cumulative effects of DDT use and its bearing on future moth populations and, in turn, changing control measures are to be observed in this orchard.—2-7-47.

Eumerus strigatus[1] Reared from Decayed Potatoes

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During October 1945, a hundred or more rotten and diseased potatoes and seed potatoes from a farm in Mars Hill, Maine were found to be heavily infested by dipterous larvae.

The samples examined were picked at random from a 12-acre field and constituted only a small percentage of the total rotten and diseased tubers. As many as seven infested tubers were found in a 3-foot section of a row, and as high as three different types of disease or rots might also be present in this 3-foot section.

Several apparently healthy tubers were found with an irregular hole through the epidermis. Larvae, similar to those mentioned above, were observed feeding on the inner tissue. The surface of the cavity, which the larvae had cut in the tuber, was pitted and very uneven, and the tissue beneath was discolored to a depth of only a few cells. The tissue beneath the discolored cells appeared unaffected by decay.

Twenty of the decayed and infested tubers were placed in 2-quart mason jars and held for emergence. No emergence occurred that fall and on November 3 the jars were placed outdoors for the winter. They were brought inside March 6 and emergence of both sexes began March 29 and continued until the last of June.

A careful check of the larval and adult characters with published descriptions (Cole 1920; Collins 1920; Heiss 1938; Hodson 1927; Wilcox 1926) disclosed this insect to be *Eumerus strigatus* Fallen,[2] an introduced syrphid that is of economic importance in the onion and narcissus growing regions. In Maine this species has been previously reported only from Bar Harbor by Johnson (1925).

A single male specimen of the common syrphid parasite *Diplazon pectoratorius* (Grau.)[3] was recovered from a pupa during rearing.

The seasonal history of *Eumerus strigatus* may be briefly summarized from Wilcox's paper (1926): This species passes the winter as fully grown larvae mostly in the host media but in some cases in the soil. During early spring the larvae leave the host and migrate into the upper two inches of soil surface and pupate. The flies emerges from one to two weeks later and are active during April and May. Mating

[1] Syrphidae.
[2] Determination checked by C. E. Parsons, Conn. Agri. Exp. Sta., New Haven, Conn.
[3] Determination by P. B. Dowden, U.S.D.A., Bur. Ent. & Pl. Quar., New Haven, Conn.

and egg laying takes place at this time. The second generation of flies emerge during June, July and August. These flies lay the eggs that develop into the last stage over-wintering larvae. In some cases, however, the larvae pupate and emerge as flies in September and thus produce a partial third generation. Wilcox's work was carried out in Oregon and, therefore, there would be a difference in dates under northern Maine conditions.

The purpose of this paper is to record the presence of *Eumerus strigatus* larvae in rotten and diseased potatoes and to point out the possible relation of this insect to some of the potato diseases.

Due to the complexities of the various potato rots it was impossible to determine the exact cause of the rot in each potato. Several of the tubers showed the characteristic rots caused by the fungi Fusaria,[1] such as the Fusarium tuber rot (wet type), the Fusarium stem-end rot, the jelly end rot, the Fusarium tuber rot such as that produced by *Fusarium trichothecioides* Wr. and the Fusarium wilt. In some cases the potatoes were infected with "black-leg," while others were so far disintegrated into a slimy rotten jelly-like mass that it was impossible to distinguish the causative agent. The majority of the infected potatoes, however, showed symptoms of the Fusarium tuber rot (wet type). Chupp (1925) stated that the Fusaria are by far the most numerous of any fungi infecting potato tubers and are able to live over winter in the soil or on the tuber. He also stated that very few are able to enter the host unless the epidermis has been injured in some way.

No reference of this species having been recovered previously from potatoes in the United States is known, although it is common in areas where onions, narcissus, iris, and other bulbs are produced. Correspondence with Florida and Maine Agriculture Experiment Stations revealed no records of this syrphid from potatoes. Several European records of *Eumerus strigatus* occurring in potatoes have been published. Zacher (1919) considered this species a primary pest of rotten potatoes. Haupfleisch (1934) stated that an infestation of *E. strigatus* involving a 5 per cent crop loss occurred in Schleswig-Holstein, where up to 40 larvae were found in a tuber. As there were no onion fields in the neighborhood and the potatoes were planted where rye had followed a green manure crop, he suspected the syrphid had probably been introduced with the seed potatoes.

Ensign's paper (1926) on the relation of the seed corn maggot, *Hylemya cilicrura* Rond., to the "black-leg" disease in potatoes, suggested to the author the possibility that some similar relation might exist between *Eumerus strigatus* and some of the various potato rots. As early as 1920, according to Collins (1920), opinions were divided as to whether the larvae of *E. strigatus* were primarily responsible for the destruction of the onion and narcissus bulbs, or whether they only attacked those bulbs which had begun to decay from other causes. Creager & Spruijt (1935) in a series of experiments on the relation of certain fungi to the larval development of *E. tuberculatus* Rond., another lesser bulb fly both closely related to and associated with *E. strigatus*, demonstrated that the larvae required the presence of certain living fungi together with the bulb media in order to complete their normal development. When the larvae were isolated on sterile media all died before reaching the pupal stage. While in the presence of the basal rot fusarium all the larvae grew rapidly to maturity. When living yeasts were used in the diet in place of fusarium, the larvae developed more rapidly and became slightly larger, and when *Rhizopus nigricans* Ehremb. or *Mucor hiemalis* Whmer. was substituted, the larvae also developed to maturity. Previously Martin (1934) found that when the larvae were caged upon healthy, bruised tissue the tissue cut from the bulb discolored and decayed several days after the larvae had been confined, and the larvae were able to develop to maturity only when the decay had started. The bulbs used in this experiment had been soaked ten days to make the tissue softer than normal for dormant bulbs. The finding of potato tubers in Maine showing no apparent signs of decay under field examination yet seriously infested with *E. strigatus* bears out Broadbent's (1925) findings that this insect is capable of attacking and injuring healthy tubers. Furthermore Hodson (1927) noted that the larvae of *Eumerus tuberculatus* were able to gain entrance into healthy bulbs and destroy them. He found 19 out of 72 healthy bulbs destroyed by this insect.

The egg deposition of the adult females often prevents the hatched larvae from selecting favorable media for development. Broadbent (1925) stated that the females of *Eumerus strigatus* were somewhat promiscuous in their egg deposition and made no distinction as to the location or condition of the host, and would lay their eggs on or near healthy bulbs. Martin (1934) further observed females laying eggs in clods of soil several feet from the nearest bulb. According to Wilcox (1926) the female deposited the majority of her eggs about one-quarter inch beneath the soil. Some eggs were deposited directly on the surface of the soil, while others were found three inches below the surface. The fact that the eggs are deposited some distance from healthy as well as decayed bulbs shows that the young larvae are capable of migrating through the soil and that they do not necessarily require the presence of certain living fungi during their early stages although, as demonstrated by Creager & Spruijt (1935), these fungi are necessary for final development.

In conclusion a summary of the above findings brings out the fact there is present in some potato fields an insect that is capable of attacking and destroying the potato tuber, and also that it has the potential ability of aiding the ubiquitous ground inhabiting fungi to gain entrance into otherwise healthy tubers and thereby aid materially in the economical loss to the grower. Only by a careful study of this insect and its relation to the known potato rots can its real economic importance be established.

The present practice of leaving all potatoes showing signs of rot or decay in the field during harvesting and the indiscriminate dumping of rotten potatoes taken from storage offers an ideal opportunity for this fly to breed in great numbers.

[1] The determination of the potato rots was based upon a series of colored plates and descriptions published by the U.S.D.A. (Misc. Pub. 98).

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The Relative Toxicity of DDT and Calcium Arsenate to Cotton Leafworm

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DDT has proven to be highly toxic to some cotton insect pests, and the increased use of the insecticide on this crop has made it desirable to compare its toxicity to the more commonly used calcium arsenate against the cotton leafworm, *Alabama argillacia* (Hbn.). The laboratory tests herein reported were conducted at College Station, Texas, during September and October, 1946.

For comparison of a 5 per cent DDT-pyrophyllite mixture and calcium arsenate, known doses of each were fed to individual third instar worms that had been collected from the field. Over 100 worms were fed doses of each insecticide and the percentage kill recorded at the end of a 48-hour period. Dosages in mg. per gm. of body weight were changed to logarithms and plotted against probits, a transformation suitable to percentages of mortality. The calculated lines of best fit are shown in figure 1.

The median lethal dose for calcium arsenate was .255 mg. per gm. body weight as compared to 1.357 for the 5 per cent DDT-pyrophyllite mixture.

[1] Technical contribution No. 1005, Texas Agricultural Experiment Station in cooperation with the Bureau of Entomology and Plant Quarantine, U.S.D.A.

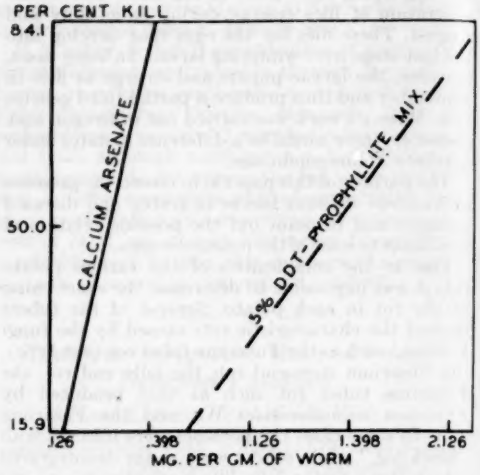

FIG. 1—Dosage-mortality curves for calcium arsenate and DDT dust to the cotton leafworm.

New Organic Insecticides to Control Hog Lice

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An infestation of the hog louse, *Haematopinus adventicius* Newm., had persisted on the college herd for many years. During this period the herdsman had treated the hogs with sprays of various commercial preparations, most of which temporarily reduced but did not eradicate the infestation.

Tests were begun in 1946 with insecticides which might not only control but eradicate the lice. Three insecticides were used during the season, DDT, DDD and Chlordane. The sprays were prepared from 25 per cent emulsion concentrates of DDT and DDD and a 20 per cent concentrate of Chlordane. An emulsifying agent was used with the latter. All spray applications contained 0.2 per cent concentration of the active insecticides. In the early trials, the pigs were held in pens and sprayed, but later were sprayed in the lots when being fed. An attempt was made to wet the backs and sides of the animals from around the ears to the tail. This was sometimes difficult because of nervousness of the hogs; however a fairly uniform coverage of the animals was obtained. The swine ranged from 6 weeks old to mature animals. No irritation or harmful effects from the insecticides were observed.

A single pig weighing about 100 pounds was treated with DDD in the first trial. This pig was kept in isolation for about 3 weeks. One month after having been returned to an infested herd, it was still

Table 1.—Results from preliminary trials against hog lice on August 5 with 0.2 per cent concentrations of three insecticides.

Number of Pigs	Average Weight, Pounds	Insecticides	Results	
			Lice Dropped	After 3 Weeks
2	125	DDD	30 min.	None
2	125	DDT	30 min.	None
2	125	Chlordane	150 min.	None

free of lice. During this period the herd had access to a concrete wallow and had wallowed in mud resulting from rain.

Six pigs were treated in the next tests (Table 1). The chlordane acted most rapidly and the lice began to drop in a few minutes. The pigs in all treatments appeared to be free of lice after about 2 hours and remained so during a period of isolation of 3 weeks.

Six brood sows were treated in late August, 7 to 10 days prior to farrowing (Table 2). These sows had been wallowing in mud and hoes were used to scrape off a considerable quantity of dry soil from their backs and sides before treatment. Lice were observed on four of the sows in spite of the adhering soil and presumably all of them were infested as they had been together for some weeks. These sows were then isolated in individual pens preparatory to farrowing. They were treated thoroughly except on the lower legs and ventral side. Apparently eradication of the lice was complete as no lice have been observed since on either the sows or their pigs.

Table 2.—Results from treatment of brood sows for hog lice on August 23 with 0.2 per cent concentrations of three insecticides 7 to 10 days prior to farrowing.

NUMBER OF SOWS	AVERAGE WEIGHT, POUNDS	INSECTICIDES	CONTROL
2	450	DDD	Complete
2	450	DDT	Complete
2	450	Chlordane	Complete

The entire herd, except the six brood sows and their litters which had been kept isolated, was treated in November (Table 3). Apparently complete eradication of the lice was obtained as none has been observed by the herdsman during the 3 months since treatment. This herd as well as the six sows and their pigs above will be checked through the spring for any evidence of reinfestation.

The owner of a herd of about 12 hogs treated them with 0.2 per cent DDT spray in late October according to our directions. He reported that newly hatched lice were observed about 2 weeks after the first treatment. A second application a few days later apparently eradicated this infestation as none has been observed during the 3 months since treatment.

Table 3.—Results from treatment of the college herd in November for hog lice with 0.2 per cent concentrations of three insecticides.

NUMBER OF HOGS	AVERAGE WEIGHT, POUNDS	INSECTICIDES	CONTROL
30	125	DDD	Complete
10	250	DDT	Complete
11	500	Chlordane	Complete

H. L. HALLER MADE SPECIAL ASSISTANT TO CHIEF OF BUREAU OF ENTOMOLOGY AND PLANT QUARANTINE

Dr. H. L. Haller, a world-famous authority in the field of organic chemistry, has been appointed special assistant to Dr. P. N. Annand, Chief of the Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture. This appointment became effective on March 13, 1947. He has served since 1937 as assistant leader of the Bureau's Division of Insecticide Investigations.

Dr. Haller is a graduate of the University of Cincinnati and of Columbia University. He was employed as chief chemist by the Jarecki Chemical Company, Cincinnati, Ohio, until 1921. He conducted research on fundamental organic problems for the Rockefeller Institute for Medical Research until 1929. He has been with the U. S. Department of Agriculture since that time.

The determination of the chemical structure of rotenone, one of the most important of the organic insecticides, is one of Dr. Haller's outstanding research contributions to science. This was accomplished in collaboration with Dr. L. B. LaForge and Mr. L. E. Smith. The Hillebrant prize of the Washington Chemical Society for 1932 was awarded jointly to Dr. Heller and Dr. LaForge for this research.

During World War II, Dr. Haller and his associates of the Bureau coordinated and executed a series of outstanding and thorough research programs in the chemistry of DDT and other insecticides for use in the form of sprays, aerosols, and dusts. They synthesized new chemical materials and converted them to maximum efficiency for military use during the war.

Dr. Haller's new assignment covers the various chemical aspects of the Bureau's problems involving the development, manufacture, and use of chemical insecticides. In addition, he will maintain relationships of the Bureau with manufacturers of chemicals which may have insecticidal properties.

ANNUAL MEETINGS IN CHICAGO

The Annual Meetings of the American Association of Economic Entomologists will be held in Chicago, in connection with the meetings of the American Association for the Advancement of Science during the week following Christmas. The dates are December 27 to 30 and the headquarters for the Entomologists will be the Congress Hotel. Requests for reservations should be sent direct to the Hotel as soon as possible as space will be limited.

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Official Organ American Association of Economic Entomologists

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Abstracting Entomological Articles and Publications

ENTOMOLOGY has become such a vast science and the literature is so tremendous that it is difficult for any one individual to have at first hand the abstracts which are necessary for him to use in his work, either for systematic or for economic purposes. While the general field of entomology is perhaps as thoroughly abstracted as any modern science, yet there are certain phases of the subject that are not abstracted at all and certain others so widely distributed that it is difficult to even consult all of the sources.

Some years ago *Biological Abstracts* was established to abstract and make available the information that was essential to the biological sciences. Because of lack of facilities it was obviously impossible for this new journal to meet all of the necessities of entomologists at once. In view of the fact that several publications were already in this field it is quite obvious that *Biological Abstracts* was not in position at the time to meet all of the competition and to supply all of the information that was not already being taken care of. However, in recent years *Biological Abstracts* has weathered the beginning difficulties of the establishment of such a publication, and is becoming more able to take care of many of the fields that were formerly somewhat neglected. A letter which the writer recently received from Dr. John E. Flynn, Editor-in-Chief of *Biological Abstracts* contains much information which seems pertinent to the situation which now confronts entomologists for better abstracting facilities. I am taking the liberty of quoting the following excerpts from this letter believing they may be of interest to entomologists and that the time may come when all of us who are members of this profession may be able to assist *Biological Abstracts* in consummating the aims of its very progressive editor-in-chief (Dr. Flynn's letter follows).

"Increasing coverage of *Biological Abstracts*, particularly over European literature that has been unavailable for abstracting for the last several years, has been our chief activity, aside from the routine work of editing abstracts and preparing and editing indexes.

"During the year 1946, we picked out some 1,200 individuals, and entered into correspondence with them, requesting them either (a) to abstract each one or more journals, or (b) to suggest an abstractor or try to interest someone locally in taking on a particular journal for abstracting. A little over 700 journal assignments were actually worked out during the year. Unfortunately for us, about 400 of these were replacements of abstractors who had resigned or become inactive. We did, however, reach a net increase of about 300 journals, bringing the number of journals abstracted up to 2,223.

"A very substantial proportion of this increase was with biologists abroad. We have been attempting to re-build the world-wide system of collaboration that *Biological Abstracts* was, prior to World War II. At the present time, about 525 periodicals from Continental Europe are being abstracted in full, for their biological content, and abstracts are being received more or less sporadically for occasional papers in some two or three hundred additional European periodicals.

"This activity is being continued and accelerated. A very substantial proportion of the European journals that are being currently abstracted in *Biological Abstracts* are not available for consultation in the United States

"In another respect, this correspondence is very timely. There is a growing realization in this country on the part of librarians, as well as scientists, that the task of rounding up and abstracting and indexing the literature on a global scale has not yet

been fully solved by any agency or in any field. Chemistry is perhaps better off than any other in this respect. *Biological Abstracts* is abstracting as I said above, somewhat more than 2,200 out of a probably 6,000 existing journals. Many fields, such as physics and the social sciences, are inadequately served by abstracting journals, or not at all.

"At the same time, there is an enormous amount of waste and inefficiency due to the existence of a large number of weak abstracting services. A survey made in 1939 revealed some 404 such abstracting services within the natural and social sciences. This, of course, includes medicine and it includes the abstracting sections that are sometimes published in journals of original publication, as well as the periodicals that are devoted exclusively to abstracting and indexing.

"The recent establishment of *Excerpta Medica* in the Netherlands has served to touch off a good deal of discussion as to just where we are going. Wherever dissatisfaction exists with respect to the abstracting of the literature, the tendency appears to be to start a new abstracting service and then if the new one does not appear to have solved the problem, another one comes along. Last Spring some French physiologists came to this country to try to interest some American organizations in aiding them in the establishment of a world abstracting system for the biological sciences which they hoped would be housed in the old League of Nations building in Geneva. Fortunately, they were persuaded not to undertake this, but to throw their support to *Biological Abstracts* in the hope that thereby, the energy which might otherwise have gone into the establishment of a competitor, might be added to what we, in this country, are able to do.

"Some of the Officers and prominent members of the American Physiological Society are hoping to have the forthcoming International Physiological Congress take a definite stand in favor of having at least one abstracting service, somewhere in the world, that would be absolutely complete for physiology. In so far as I have participated in these discussions, they do not necessarily oppose having multiple abstracting services; they are merely demanding that one, at least, shall be built up to a state of completeness. If various groups want a more penetrating and selective covering of a limited field, they should, of course, be in position to provide it.

"In some quarters there is a feeling that *Biological Abstracts* represents t e nucleus of such a world-wide system for biology but that it may have outgrown its purely American phase of development.

"The Union of American Biological Societies, at the Christmas meetings in Boston, passed a resolution which was directed to UNESCO, suggesting that UNESCO study this prob em with the view to bringing the several abstracting services in the biological fields into amalgamation or, at least, close cooperation, and something was said, if I recall correctly, about the desirability of having every biologist throughout the entire world to see to it that each of his own papers is abstracted in the central service.

"Some of the trustees of *Biological Abstracts* have been discussing this question with regard to further development of *Biological Abstracts* and they are very receptive to the idea that UNESCO should be consulted at an early date. I think there would be, among the trustees, a fairly general agreement as to the desirability of some form of international control, but the discussions to date have not gone much beyond that point.

"The relationship between a broad, comprehensive service, such as *Biological Abstracts* was designed to provide, and the more specialized services, such as *Zoological Record*, *Horticultural Abstracts*, and the like, is a problem that deserves very serious thought. These highly specialized services, particularly the British ones, became in general highly efficient in serving limited fields. In our enthusiasm for a bigger and more comprehensive service, covering the entire literature and bringing all of its contributions annually into a single index, we should not lose sight of the special needs of the various research fields.

"At several of the recent annual meetings of the Board of Trustees I have discussed plans for pooling abstracts. Such plans were in operation between the British services and ourselves during the war; American abstractors who were covering publication unavailable in Britain were asked to prepare carbon copies

of all of their abstracts and these were supplied to British abstracting journals that desired them. We have a similar working arrangement with the Experiment Station Record. A year ago I proposed that each abstracting service equip itself with a photo-copying machine and that, by correspondence and frequent conferences of abstracting journal editors, arrangements might be made to have each editor responsible for the procurement of abstracts of a definite part of the literature, supplying photo-copies of these to all the other abstracting services interested in them. Nothing came of this suggestion but I still believe in it.

"I would be very glad to discuss these and other topics with prominent entomologists.

"We could explore the possibilities of establishment of a new section of *Bio.ogical Abstracts*, to serve entomology. It would be helpful also if more of the entomologists actually knew our problems from the inside.

"If we had adequate funds there are many important things that we could undertake almost immediately. German research literature is reaching this country in enormous tonnage—much of it being microfilm copies of termendously important research papers that were withheld from publication in Germany for military reasons. Japanese literature is also beginning to reach this country. I heard in Washington last week of their having received a shipment of some 1300 items—mostly in the Japanese language. We could hire Japanese translators and station them in the Library of Congress, to abstract this literature, if our budget permitted."

E. O. ESSIG

NORTH CENTRAL STATES BRANCH AMERICAN ASSOCIATION OF ECONOMIC ENTOMOLOGISTS

Proceedings of the Second Annual Meeting Hotel Ft. Des Moines, Des Moines, Iowa, March 27–28, 1947

The entomologists of the North Central States held their usual type of informal meeting in Des Moines, Iowa, March 27 and 28. General discussion sections were carried on under the following topics:

Insecticides
European Corn Borer
Insects Affecting Man and Domestic Animals
Fruit and Vegetable Insects
Extension Entomology
Beekeeping
Insects of Greenhouses, Ornamentals, and Shade Trees—Equipment
Field Crop Insects

Four guest speakers contributed to the success of the meetings: Dr. E. N. Cory, President of the, American Association of Economic Entomologists, brought greetings from the parent society and outlined the committee functions of the American Association. Dr. B. P. Uvarov, Director of the Anti-Locust Research, Research Centre, London, England, gave an interesting banquet address on the problems of locust eradication. Dr. G. Fraenkel, Imperial College of Science and Technology, London, England, gave an address during the opening session on "The Vitamin Requirements of Insects." Dr. F. G. Holdaway, Entomologist, Agricultural Experiment Station of Honolulu, Hawaii, gave a talk during the second general session on "The Major Economic Pests of the Hawaiian Islands."

Business Session

REPORT OF COMMITTEE ON RESOLUTIONS

WHEREAS the North Central States Branch of the American Association of Economic Entomologists has just completed another excellent annual meeting, therefore

BE IT RESOLVED that we express our appreciation to the local Committee on Arrangements (consisting of H. M. Harris, H. L. Chada, Harold Gunderson, Ephriam Hixson and C. H. Richardson); the Program Committee (consisting of R. C. Smith, G. E. Gould and J. H. Lilly); and the officers of the North Central States Branch for their efforts in behalf of the successful meetings.

WHEREAS the facilities made available for the meetings by the Hotel Fort Des Moines and the efforts of the hotel management to meet our needs have contributed much to the success of our meetings, therefore

BE IT RESOLVED that we express to the management our appreciation.

WHEREAS we have had the unusual and valuable experience of having addresses from three entomologists of renown from without continental United States who have contributed much to the success of our meetings, therefore

BE IT RESOLVED that we express our appreciation to

Dr. G. Fraenkel, of the Imperial College of Science and Technology, London, England;

Dr. B. P. Uvarov, Director of Anti-Locust Research, Research Centre, London, England; and

Dr. F. G. Holdaway, Entomologist at the Agricultural Experiment Station of Hawaii, Honolulu.

WHEREAS the attendance at Branch Meetings by the President of the Parent Association is of direct benefit to both the Association and its Branches, therefore

BE IT RESOLVED that the American Association of Economic Entomologists be commended on the recent adoption of this practice.

WHEREAS the Pest Survey publications prior to the war were of material aid to the entomologists throughout the country, therefore

BE IT RESOLVED that the Bureau of Entomology and Plant Quarantine be requested to resume the monthly publication with more detailed reports as was done prior to World War II. The importance of this service would justify the expenditure of additional funds if necessary.

WHEREAS confusion sometimes exists among consumers, retailers, manufacturers, and research organizations regarding recommendations for proper usage of insecticides, therefore

BE IT RESOLVED that the membership of this organization, as individuals and groups, make special efforts to issue recommendations which are as uniform as practical for the uses of insecticides during an approaching season at earlier dates than have predominated in the past.

WHEREAS H. R. *1237* known as "Federal Insecticide, Fungicide and Rodenticide Act" now under consideration by Congress is much needed legislation and has been agreed upon by industry and responsible officials, therefore

BE IT RESOLVED that the North Central States Branch of the American Association of Economic Entomologists, request its early enactment.

WHEREAS properly prepared charts and lantern slides can be helpful in presenting data and,

WHEREAS members at meetings of the North Central States Branch as well as those of the parent Association, are still utilizing visual aid materials far below acceptable standards, therefore

BE IT RESOLVED that the program committee be authorized to set up standards for all such materials similar to those outlined by M. P. Jones in the paper entitled, "Use of Illustrative Material in Presenting Subject Matter," or any other standards it may deem proper, and request speakers using such aids to conform to these requirements.

BE IT FURTHER RESOLVED that as a means of stimulating interest in the use of visual material, the program committee consider some arrangement whereby a selection of black and white prints, color prints and color transparencies on entomological subjects could be collected from the membership for exhibition in conjunction with the annual meeting of the North Central States Branch.

Signed: G. M. LIST, *Chairman*
H. G. INGERSON
L. F. STEINER
R. H. DAVIDSON
E. H. FISHER

TREASURER'S REPORT

	Credits	
Balance in Treasury, March 27, 1946	$ 10.00	
95 copies 1946 Proceedings @ $2.00	190.00	
Bank interest to January 1, 1947	.79	
Total credits		$200.79
	Debits	
Starting addressograph and mailing charges	$ 18.54	
Mimeographing	.84	
Preparation of Proceedings		
Paper, processing plates, and printing	99.00	
Stamps	9.10	
Clerical help	5.00	
Refund for duplicate order of Proceedings	2.00	
Bookkeeping materials	1.11	
Total debits		135.59
Balance		$ 65.20

JAMES W. APPLE, Secretary-Treasurer

REPORT OF AUDITING COMMITTEE

Treasurer's report examined and approved by
WILLIAM P. HAYES
GEORGE C. DECKER

Recorder for 1947

R. A. Blanchard, Urbana, Illinois, was appointed Recorder to prepare a record of the proceedings of the 1947 meeting for proper distribution.

Committee to Revise the Branch Constitution

The following committee was appointed to revise our new constitution: George C. Decker, Chairman, Ray Hutson, and John Lilly.

Committee on 1948 Meeting Place

To the executive Committee was assigned the task of arranging for the time and place for the 1948 meeting.

Committee to Select Officers

The membership selected G. C. Decker, C. J. Weinman, and C. W. Kearns as a committee to select new officers for the Branch. This committee of three selected the following officers for 1947: President, H. M. Harris; Vice President, P. O. Ritcher; Secretary-Treasurer, J. W. Apple.

The following persons registered during the 1947 meeting:

ARKANSAS

Miner, F. D.

COLORADO

Daniels, Leslie B.
Compton, C. C.
Hoerner, John L.
List, George M.
McCauley, W. E.
Mickle, Gordon T.
Newton, J. H.
Wakeland, Claude

CONNECTICUT

Glass, Edward H.
Gleissner, Bruce D.
Tate, H. Douglas

DELAWARE

Woodbury, E. N.

ILLINOIS

Apple, J. W.
Benham, John F.
Bevernick, A. W.
Bigger, J. H.
Blanchard, R. A.
Brower, D. G.
Bruce, W. N.
Bussart, J. E.
Chandler, S. C.
Dahm, Paul A.
Decker, George C.
Dickison, William
Ferguson, William
Hayes, William P.
Johnson, Donald Ross
Kearns, C. W.
Lewis, David P.
Ludvik, George F.
March, Ralph B.
Paullus, J. H.
Petty, H. B.
Piesbergen, N.
Weinman, Carl J.
Wright, J. M.

INDIANA

Davis, J. J.
Fahey, Jack E.
Gould, George E.
Krausche, Kenneth K.
Schlosberg, Morris
Steiner, L. F.
Thomas. E. L.
Ulman, P. T.
Vance, Arlo M.
Walter, E. V.

IOWA

Anderson, A. C.
Barakat, John S.
Chada, Harvey L.
Doty, L. W.

Du Chanois, Francis Robert
Gunderson, Harold
Hagen, Vern S.
Hardy, D. Elmo
Harris, H. M.
Hollenbeck, Carlos
Keshlear, Barr
Knight, H. H.
McGuire, Judson U., Jr.
Paddock, F. B.
Park, O. W.
Reed, John K.
Reindl, R. G.
Rorman, Wayne D.
Sharp, S. S.
Tauber, O. E.
Wilson, Elmer L.

KANSAS

Bartholomae, C. W.
Butcher, Fred D.
Cotton, R. T.
Frankenfeld, J. C.
Goodhue, Lyle D.
Hungerford, H. B.
Parker, R. L.
Smith, Roger C.
Walkden, H. H.

KENTUCKY

Price, W. A.
Ritcher, Paul O.

MARYLAND

Cory, Ernest N.
Haeussler, G. J.
Poos, F. W.
Reed, L. B.
Sasscer, E. R.

MICHIGAN

Dieter, Curtis E.
Gerlach, Charles F.
Graham, S. A.
Ingerson, H. G.
Kenaga, E. E.
Sherman, Franklin III

MINNESOTA

Aamodt, T. L.
Ali, Mir Hamedi
Benjamin, D. M.
Butcher, James W.
Buzicky, Albert W.
Doner, M. H.
Granovsky, A. A.
Harris, H. H.
Hodson, A. C.
Kretzschmar, Gerhard, P.
Mickel, Clarence E.
Tsao, C. H.
Yao, K.

MISSISSIPPI

Lyle, Clay

MISSOURI

Adams, Lloyd E.
Beaver, Bernard F.
Becker, Edward C.
Broadus, Edward P.
Brooks, J. W.
Brower, Hollis H.
Cuff, Ray L.
Evans, Sterling
Hyry, Edmund C.
Jenkins, Lee
Jones, George D.
Magner, J. Marshall
Nelson, Paul A.
Portman, Roland W.
Stone, Dr. P. C.
Swisher, E. M.
Thomas, George W.
Wakeman, Robert I.

NEBRASKA

Fuxa, Ray
Hill, Roscoe E.
Hixson, Ephriam
Muma, Martin H.

NEW HAMPSHIRE

Farrar, M. D.

NEW JERSEY

Driggers, B. F.
Ferguson, George R.
Heal, Ralph E.
Matthysse, John G.
Osmun, John V.

NEW YORK

Adams, J. F.
Darley, M. M.
Griffin, Robert H.
Harris, C. S.
Sanders, J. G.
Weed, Alfred
West, Harry

NORTH DAKOTA

Munro, J. A.
Post, Richard L.

OHIO

Arbuthnot, K. D.
Batchelder, C. H.
Bradley, William G.
Brunn, Lynn K.
Cutright, C. R.
Davidson, Ralph H.
Dicke, F. F.
Everly, Ray T.
Houser, J. S.
Milliron, H. E.
Parker, D. E.
Parks, T. H.
Peter, Kaspas
Sutton, Robert

OKLAHOMA

Whitehead, F. E.

PENNSYLVANIA

Dietz, Harry F.
Johnson, Martin E.

TENNESSEE

Stanley, W. W.

WEST VIRGINIA

Cooper, James F.

WISCONSIN

Bess, Henry A.
Carroll, Francis E.
Chamberlin, T. R.
Chambers, E. L.
Chapman, R. K.
Dexheimer, F. J.
Fisher, E. H.
Fluke, B. C.
Fluke, C. L.
Kido, G. S.
Lilly, J. H.
Medler, John T.
Mettler, Fred
Olson, Ken

WYOMING

Denning, D. G.
Titensor, Claine E.

WASHINGTON, D.C.

Bishopp, F. C.
Haller, H. L.
Jones, M. P.
Packard, C. M.
Porter, B. A.

LONDON, ENGLAND

Uvarov, B. P.
Fraenkel, G.

HONOLULU, HAWAII

HOLDAWAY, F. G.

J. W. Apple, *Secretary-Treasurer*